MODEL 650
SWEEP OSCILLATOR

plug-in units

USING VARIAN BWO TUBES
WITH GRID LEVELING

657KE 675

ALFRED ELECTRONICS 3176 PORTER DRIVE, PALO ALTO, CALIF.

INSTRUCTION MANUAL

MODEL 650
SWEEP OSCILLATOR

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USING VARIAN BWO TUBES
WITH GRID LEVELING

65 7KE (Model) 675 (Serial)

☒ Grid leveled, internal sampling
☐ Grid leveled, external sampling

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MANUAL #650-3,-5

Date	ECO#	Effective Serials	Revision
9-4-68		All	In Section 5, p. 5-5, the 3rd line of paragraph 5.3.3 m. should read: "CCW rotation limit (labeled 0) unless the pip appears".
9-19-68	13770	All	In Section 6, A12 Parts Lists, insert Alfred Part No. 81-20, Diode, IN4385, as alternate usage for A12CR1 and A12CR3 (IN459).
3-5-69		All	In Section 6, page 6-1, under C. Leveler Amplifier PC Board All, change (Assembly 950636) to (Assembly 950621). In Section 4, Fig. 4-4, insert IN4385 as alternate usage for A12CR1 (IN459).
10-27-8	13788	All	In Sections 4,5,6, and 7 delete all reference to the anode protection circuit A19 (assy. 951619; schematic 907307) which was formerly used with Varian Tubes only. A simple 10 ma fuse is now used with Varian Tubes, as shown on schematic 907053. dated 10/68. Add to parts list for PIN Diode Plug-in Chassis Assy: F1 121-27 Fuse, 1/100 A, Type 8AG, 250 V (used with Varian tubes only) CR1 81-135 Diode, EH 400 (used with Varian tubes only)
6-23-69	14164	All	In Section 7, on the apron of Schematic C900713, make the following additions in Tube (BWO) usage, Diode Shaper PC Board Assy., No., and R1 thru R11 in the Table of Resistor Values: Freq. Model Tube Type Alfred Tube No. Diode Shaper PC Board 2 to 4 652 652C 652K 652CK Watkins/Johnson 112-095 951877 (Resistor Values R1 - 107K, R2 - 121K, R3 - 750K, R4 - 309K, R5 - 422K, R6 - 348K, R7 - 287K, R8 - 536K, R9 - 267K, R10 - 392K, R11 - 383K The above additions should also be reflected in Table 1-1 (Section 1).

Date	ECO#	Effective Serial's	Revision
7-29-69	14308	Serial # Effective:	(S/N 371 & above for Plug-in units above 12.4 GHz.) (S/N 776 & above for Plug-in units below 12.4 GHz.) In Section 6 List of Assemblies, insert usage of Elevated Supply PC Board A12 (Assy. 951917) and also insert C907377 as Schematic usage for Assy. 951917. On page 6-2, substitute Enclosure 1 (Errata page 3) for the Elevated Supply (Assy. A12) Parts List. In Section 7, delete usage of Schematic C900869 effective per the S/N indicated Schematic C907377 has been inserted for Plug-ins containing Elevated Supply Assy. 951917. In Section 4, Fig. 4-4, make the following changes: A12R4 is 820 Ω, 2 w, 5% Delete A12C2 A12R7 is 10K, 2 w, 5% Delete A12C4 Delete A12R6 & A12R8 and substitute shorted connections. Delete A12C3 A12Q1 is 2N2405 Delete A12CR4 Delete A12CR5 & A12CR6 and sustitute shorted connections.

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NOTE: This Manual Applies to 650 Models without C Suffix having Varian BWO Tubes.

Table 1-1. Specifications of Oscillator Plug-in Units.

Frequency GHz.	6400 Model No.	650 Model No.†	** Tube Manufacturer	Tube No.	Power Output (mw)yy	Power Variation Leveled dbtt	Residual FM (Max.Khz.)	Diode Shaper PC Board	Samplery	Sampler Attenuator	Low Pass Filter
1 to 2	6410 thru 6415	651 651C* 651K 651CK*	Stewart	SE 214C	80	±0.3	30	950636	951099	1151x	256-6y
			Varian	VA 183A	70			951600		951253xx	xxxx
1.4 to 2.5	6410-1 thru 6415-1	651-S1 651C-S1 651K-S1 651CK-S1	Stewart	SE 219-3	80	±0.3	30	950637	950781	1151-1x	
			Varian	VA-186AA	70					951254xx	xxxx
1.7 to 4.2	6420-1 thru 6423-1	652-S5 652C-S5 652K-S5 652CK-S5	Stewart	SE 215-6	35	±0.5	30	950858	950908		256-9y
			Varian	VA-184AA	30						xxxx
2 to 4	6420 thru 6425	652 652C 652K 652CK	Stewart	SE 215A-2	70	±0.3	30	950638	951100	1152x	256-2y
			Varian	VA 184A	50			951601		951255xx	xxxx
3.5 to 6.75	6430-1 thru 6435-1	653-S1 653C-S1 653K-S1 653CK-S1	Stewart	SE 221-1	40	±0.4	50	950640	950783	1153-1x	256-4y
			Varian	VA 185AA	30			951602		951257xx	xxxx
3.7 to 8.3	6430-2 thru 6433-2	653-S2 653C-S2 653K-S2 653CK-S2	Stewart	SE 211B-7	10	±0.5	50	950965	950896		256-8y
			Varian	VA 185AB	10			951610			xxxx
4 to 8	6430 thru 6435	653 653C 653K 653CK	Stewart	SE 211A-B	40	±0.5	50	950639	950784	1153x	256-1y
			Varian	VA 160A	25			950932		951256xx	
7 to 11	6440 thru 6443	654 654C 654K 654CK	Varian	VA 173A	40 15	±0.5	75	950641	951101		256-5y
7 to 12.4	6440-1 thru 6443-1	654-S1 654C-S1 654K-S1 654CK-S1	Varian	VA 173A	40	±0.75	75	950647	951101		256-5y
			Watkins-Johnson	WJ 2039-3	15			951603			
8 to 12.4	6450 thru 6453	655 655C 655K 655CK	Varian	VA 173E	80	xxx	75	950642	950786		256-5y
			Watkins-Johnson	WJ 2039-2	50			951604			
10 to 15.5	6460	656	Varian	VA 177A	35		150	950643		950866***	
12.4 to 18	6470 6471	657 657K	Varian	VA 162A	40 25	±0.8	150 200	950644	950892	— 950815***	
18 to 26.5	6480	658	Varian	VA 163A	20		200	950645		950868***	
26.5 to 40	6490	659	Varian	VA 164A	>5		350	950646		950867***	

* C suffix indicates PIN DIODE Attenuator **All Varian tubes use Anode protection circuits. ***Flap attenuator

x For External use with Model 650 only xx Model 64( )5 only xxx±0.5 (8.2 to 12.4 Ghz.); ±0.7 (8.0 to 12.4 Ghz.) xxxxSelf-contained in BWO

† K suffix indicates rf leveling sampler mounted internally. Basic model requires an external sampler for leveling.

tt Level variation limits shown for units with internal leveler-sampler can be achieved with at-the-load leveling in all units, by use of a suitable external sampler.

y Used only on units (with K suffix) having internal sampling.

yy Upper figure indicates rated maximum unleveled output from units without internal sampling; lower figure indicates rated maximum leveled output from units with internal sampling.

PULSE MODULATION VOLTAGE REQUIRED AT AM EXT JACK: The pulse modulation voltage required for external on-off modulation varies with the response speed required. A signal of + 10V will turn the rf output on with a rise and fall time of about 1 μs in all units, in the unleveled mode. For high-speed, ac-coupled pulse modulation in the unleveled mode with rise and fall time of ≈ 0.1 μs, a pulse amplitude of typically +45 volts with 50 Ω source impedance is required in all units having Stewart (or Watkins-Johnson) BWO tubes; and a pulse amplitude of typically + 100V with 50 Ω source impedance is required in all units having Varian BWO tubes. During leveled operation, a signal of + 10V will turn the rf output on with a rise time of about 10 μs in units having PIN diode leveling, and about 20 μs in units having grid leveling.

Specifications subject to change without notice. Data not shown was unavailable at press time.

SECTION 1

GENERAL INFORMATION

1.1 SCOPE OF MANUAL

This manual covers the group of Oscillator Plug-in units of the ALFRED Model 650 Series using Varian BWO tubes with grid leveling. All standard plug-in units covered by this manual are included in Table 1-1.

Table 1-1 also includes performance information pertinent to each plug-in unit, and identifies the components which constitute the main differences between each plug-in unit of the group. These are the backward-wave oscillator (BWO) tube, the diode shaper board which matches the high voltage cathode supply output to the tube characteristic, the rf output low-pass filter, (where used) and the internal sampler for K-suffix plug-in units. These component differences are required for operation in the different frequency bands shown in Table 1-1.

This manual should be used as a supplement to the basic Model 650 Instruction Manual. That manual includes all necessary information for operating the Model 650 with any plug-in unit installed. This plug-in unit manual gives supplemental descriptive, theory, and maintenance information pertinent to the plug-in units using Varian BWO tubes with grid leveling.

1.2 DESCRIPTION OF PLUG-IN UNIT. Each plug-in unit is a modular rf head assembly designed to operate with the ALFRED Model 650 to constitute a microwave sweep oscillator. All plug-in units can be operated interchangeably in any Model 650, and no adjustments are required, either on the Model 650 or the plug-in unit, when interchanging plug-in units. Thus, by using several plug-in units interchangeably, a versatile, wide-range oscillator capability is provided at minimum expense, and operation can be extended into additional bands when desired by purchasing additional plug-in units.

Plug-in units are available covering frequencies from 0.25 Gc to 40 Gc (see Table 1-1). All plug-in units are equipped with an internal leveler-amplifier, and can provide leveled rf output when used with an external sampler. Those plug-in units with model numbers having a "K" suffix are also equipped with an internal sampler to permit self-contained leveling. These units have a front panel RF SAMPLER INT-EXT switch to select either internal or external sampling.

The plug-in unit chassis is fabricated from aluminum to avoid interference with the magnetic field of the BWO tube, and the top and bottom panels of the plug-in unit completely enclose the tube for shielding and mechanical protection. The tube is mounted on a center plate in the forward portion of the chassis. The leveler-amplifier and diode shaper plug-in PC boards are located in the rear compartment of the chassis. The elevated supply and (where used) anode protection circuits are located in the tube compartment in the forward portion of the chassis.

The frequency dial plate corresponding to the rf output band of each plug-in unit is stored in the top storage compartment of that plug-in unit, as shown in Figure 2-1 of the Model 650 Instruction Manual. Installation of this plate onto the dial plate area of the Model 650 calibrates the Model 650 for operation with the corresponding plug-in unit.

1.3 OTHER DOCUMENTATION FURNISHED WITH MANUAL.

An envelope at the rear of this manual contains factory performance-test data for the instrument and data for the BWO tube, as follows:

a. "ADDENDUM A" listing instrument model and serial number of the instrument and the particular values of factory-selected components used; and also listing the tube parameters pertinent to the tube originally shipped in the instrument.

b. A maximum power output performance plot of the plug-in unit made during final swept-frequency testing at ALFRED.

c. For units with internal leveling (K suffix models) a plot similar to b but showing performance in the leveled condition.

SECTION 2

INITIAL INSTRUCTIONS

2.1 GENERAL. Refer to Section 2 of the Model 650 Instruction Manual.

CAUTION

The BWO tube housing contains a strong permanent magnet. This magnet will attract magnetic materials brought near it, and the tube may be damaged (1) by being struck by such materials, and (2) by permanent alteration of its magnetic field by being exposed to such materials. Use only non-magnetic screwdrivers and other tools when working around the plug-in unit, and remove your wrist watch to avoid magnetic damage to it. The plug-in unit should be kept at least six inches from magnetic materials.

When a plug-in unit is removed from the Model 650, or if a unit is received separately, store it in a suitable shielding container, such as the ALFRED Model 9000 Storage Container, or on wood and at least six inches from magnetic sources.

SECTION 3

OPERATING INSTRUCTIONS

Refer to Section 3 of the Model 650 Instruction Manual.

3.1 REMOVAL, INSTALLATION, AND INTERCHANGING OF PLUG-IN UNITS IN THE MODEL 650.

CAUTION

When changing Plug-in units, turn the POWER switch off and wait 15 seconds before removing the installed Plug-in unit and inserting the other Plug-in unit, to permit decay of the power supply voltages. Then carry out the standard turn-on procedure.

3.1.1 REMOVAL OF A PLUG-IN UNIT FROM THE MODEL 650. To remove a plug-in unit from the Model 650, release its panel LOCK knob by turning fully CCW, and then pull the unit out of the Model 650 by pulling on the LOCK knob. Remove the frequency dial plate for that plug-in unit from the Model 650 panel and attach to the underside of the storage compartment door in the top of the plug-in unit, using the knurled screws removed with the plate. (See Figure 2-1 of the Model 650 Instruction Manual.)

3.1.2 INSTALLATION OF A PLUG-IN UNIT IN THE MODEL 650. To install a plug-in unit in the Model 650, first remove the frequency dial plate from the storage compartment door of that plug-in unit and install it into the calibrated position on the Model 650 panel. (See Paragraph 2.6 and Figures 2-1 and 3-1 of the Model 650 Instruction Manual.) Make sure the plug-in unit LOCK knob is turned fully CCW so the lock arm will clear the Model 650 panel opening and will enter far enough to actuate the safety interlock switch. Then insert the plug-in unit through the Model 650 panel and lock in position by pressing in on the LOCK knob and turning it fully CW.

3.1.3 INTERCHANGING PLUG-IN UNITS IN THE MODEL 650. To interchange plug-in units, follow the procedure of Paragraphs 3.1.1 and 3.1.2 above. The Model 650 is properly calibrated for operation with the new plug-in unit by installation of the frequency dial plate for that unit. No adjustments are required.

3.2 FUNCTIONS OF PANEL CONTROLS, INDICATOR, AND CONNECTORS.

See Tables 3-1 and 3-2 of the Model 650 Instruction Manual. Controls and connectors on the plug-in unit are covered at the end of each table.

3.3 FUNCTION OF TIME METER

The time meter, visible when the storage compartment door is open, is provided as an aid in monitoring the rated number of heater hours of the BWO tube. A mercury line in the meter capillary tube moves from the "0" to the "1" position linearly during a preset number of hours of heater operation, in accordance with the value of factory-selected resistor R11 (normally 2500 hours). The rated number of heater hours for the BWO tubes used in plug-in units covered by this manual is indicated in the Tube Warranty and Replacement Procedure sheet included at the back of this manual. Do not replace the BWO tube just because the time meter has moved full scale. Tube performance rather than time meter indication should be the criteria for tube replacement. Refer to Paragraph 5.4.1 for analysis of BWO tube failure indications.

3.4 OPERATING PROCEDURES

Section 3 of the Model 650 Instruction Manual includes detailed instructions for operation of the plug-in unit and its controls. See paragraph 3.12 of that manual for a discussion of operation with leveled rf output and use of the POWER LEVEL controls.

NOTE: When external leveling is desired on units without internal sampling, it may be necessary to add a low-pass filter externally, between the RF OUTPUT jack and the external sampler, to avoid ripples in the leveled output near the upper end of the band. Units with an internal sampler contain a built-in low pass filter which eliminates the need for an external filter when external leveling is used. Some Varian tubes (See Table 1-1) also contain a built-in filter.

SECTION 4

CIRCUIT DESCRIPTION

4.1 BLOCK DIAGRAM DESCRIPTION

A basic block diagram of the plug-in unit is included in Figure 4-1 (Sheet 2) of the Model 650 Instruction Manual, and the basic functions of the plug-in unit and its three Main PC Boards (A11, A12, and A13) are described in that manual, in Paragraph 4.1 and Table 4-1.

The backward-wave oscillator (BWO) tube located in the plug-in unit supplies the sweep oscillator rf output. By applying proper drive signals to the BWO tube, the plug-in unit converts the dc power and control signals supplied by the Model 650 chassis into proper-frequency rf output signals with the required modulation and/or leveling. Power supply outputs from the Model 650 are standardized for all plug-in units where possible; but because of the different cathode and anode biasing requirements of different-frequency BWO tubes, the level-controlling feedback for these two supplies is developed in the plug-in units.

The cathode supply voltage applied to the BWO tube controls the rf output frequency. The cathode supply output line passes through the Elevated Supply PC Board A12, where it is connected to the 0-line. It then connects directly to the BWO tube cathode. The cathode supply output varies from -150 V to -2500 V, as required to develop sufficient feedback through the diode shaper board to exactly cancel the linear 0 to +15 V frequency-determining control signal developed by the dc control circuits in the Model 650. The Diode Shaper PC Board A13 is shown in Figure 4-1 (Sheet 1) of the Model 650 Instruction Manual.

The diode shaper board monitors the instantaneous output of the cathode supply through a string of feedback dropping resistors. These resistors drop the voltage value monitored to a range below -15 V, commensurate with the low-voltage control signals. This board then processes the low-voltage monitoring signal to develop non-linear feedback which corresponds to the non-linear cathode voltage-vs-output frequency performance curve of each BWO tube. This arrangement permits linear frequency control with a linear dial and linear control voltages.

The BWO tube helix operates at near-ground potential, being connected to ground through a one-ohm resistance (A12R2 in parallel with A7R14), as shown in Figure 4-10 of the Model 650 Instruction Manual.

The anode supply output line is coupled to the BWO tube through the elevated supply, as shown in Figure 4-11 of the Model 650 Instruction Manual. The elevated supply develops feedback across A12R11, A12R14 to control the anode supply voltage to the level required by each tube. A12R14 is factory-selected, and A12R9 is factory-adjusted to set the proper voltage.

The grid voltage applied to the BWO tube controls the rf output level. The grid voltage is developed by the circuit of A12Q1 as shown in Figure 4-16 of the Model 650 Instruction Manual. This circuit operates within the range of $V_{cathode}$ and -100 V below $V_{cathode}$. The transfer oscillator supplies zero current drive when no modulation or leveling signal is present. This cuts off A12Q1, bringing the grid close to cathode potential for full rf output power. In this condition, the only drop across A12L1 and A12R3, A12R4, and A12R5 is that due to grid current.

To turn off the rf output during the "off" half-cycle of square wave modulation or during the "rf off" mode, the transfer oscillator generates a current of about 35 ma which develops a drop of 61V across A12R4 and A12R5 so that the effective grid-cathode bias of the BWO tube is -61V. This is sufficient to completely cut off the electron beam in the tube, providing an infinite on-off ratio.

For control of output level in the leveled mode, the tube rf output is reduced during the sweep by a variable amount as required to produce constant power equal to that available at the point of minimum unleveled output. The transfer oscillator generates an analog current drive signal related to the amount of level reduction required, ranging from 0 to less than 35 ma. Transistor Q1 then biases the BWO tube grid as necessary to reduce power to the required steady level.

The Leveler-Amplifier PC Board A11 generates the level-correction control signal for the transfer oscillator in leveled operation. It receives a fixed-level reference signal from the modulator, and a signal proportional to the instantaneous output level from the internal or external sampler. The reference signal level from the modulator can be adjusted by the POWER LEVEL control to achieve balance with the sampler signal at the desired rf power level. The reference signal drops to zero when modulation is simultaneously applied to the BWO tube, to prevent the leveler from attempting to correct for such desired modulation.

Whenever the reference and crystal detector signals do not cancel, the differential input stage of the leveler-amplifier generates a correction signal which is amplified and applied to the transfer oscillator. The transfer oscillator, in turn, drives Q1 in the elevated supply as described above. The sensitivity of the feedback-stabilized leveler-amplifier is high enough that it holds the rf output level within a fraction of a db regardless of the unleveled characteristic of the tube. As the output sweeps through frequencies where the unleveled characteristic is several db higher than the minimum-power point in the band, the leveler increases the correction signals in response to the increased crystal output, and prevents the level from increasing more than about 0.3 db.

Whenever power is leveled over the full range being swept, a variable-level positive signal is continuously supplied to the transfer oscillator.

When such a positive output signal is continuously supplied, it also drives an amplifier stage to cut off power from the UNLEVELED WHEN LIT light. The absence of a positive leveler

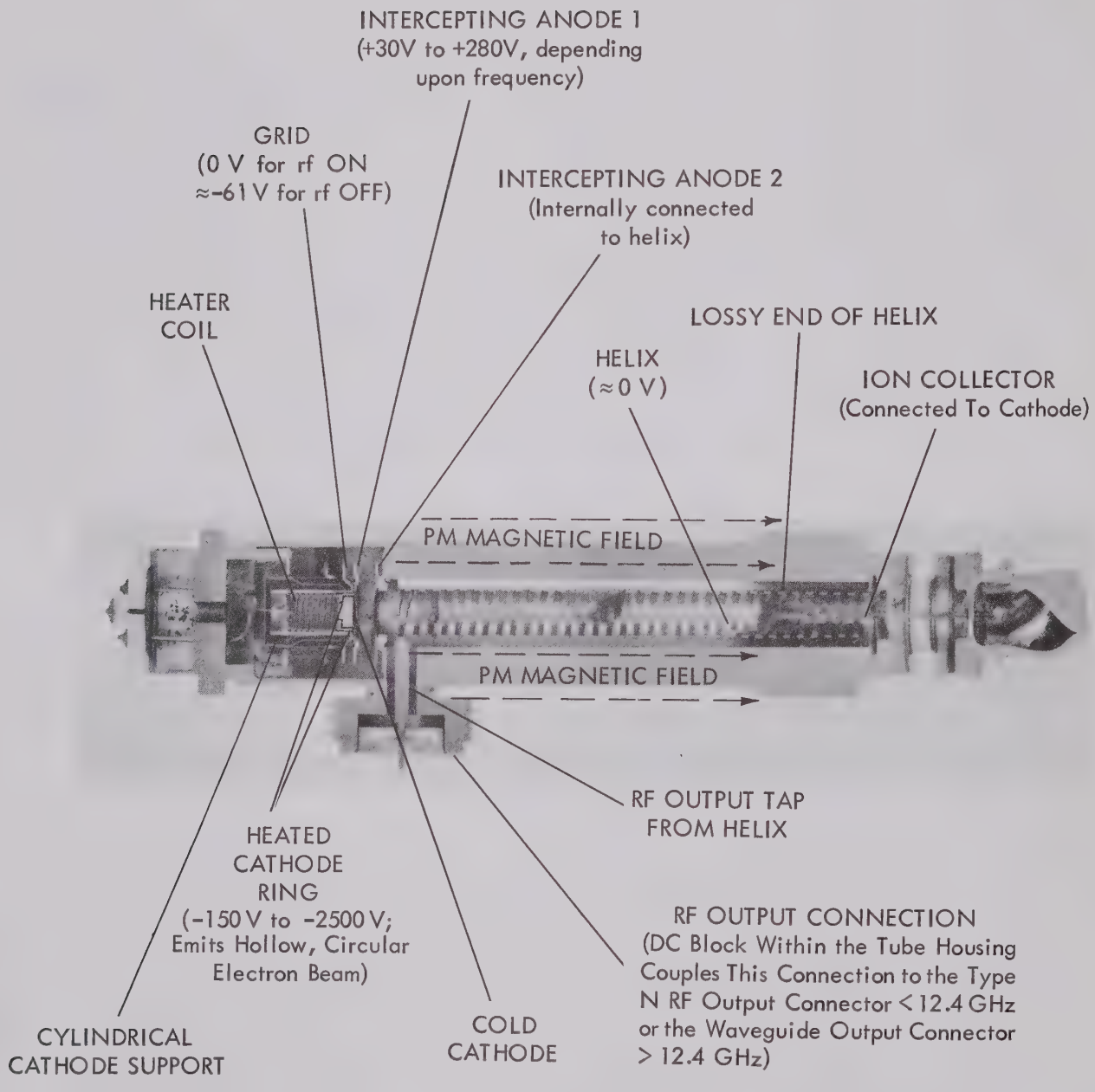
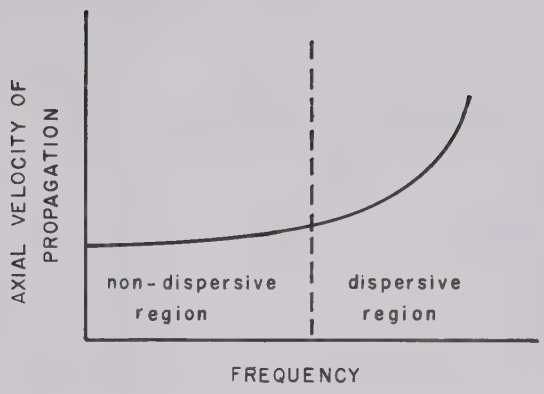
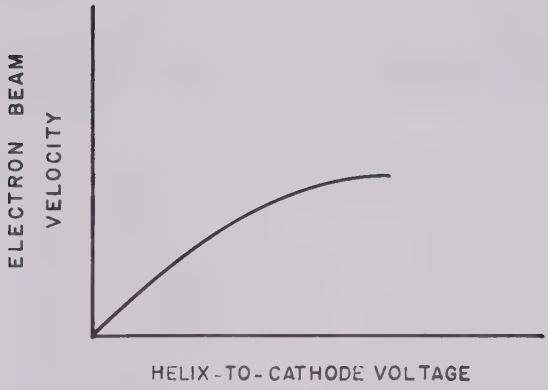


FIGURE 4-1. BACKWARD WAVE OSCILLATOR TUBE



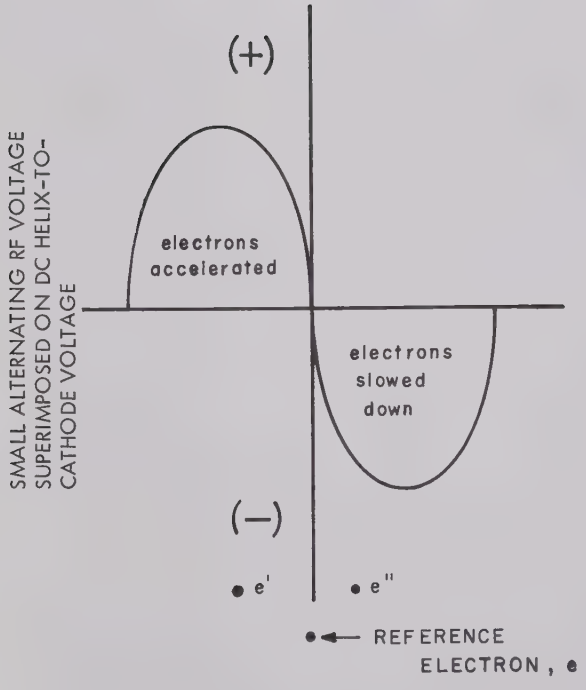
AXIAL VELOCITY OF PROPAGATION VS. FREQUENCY

(A)



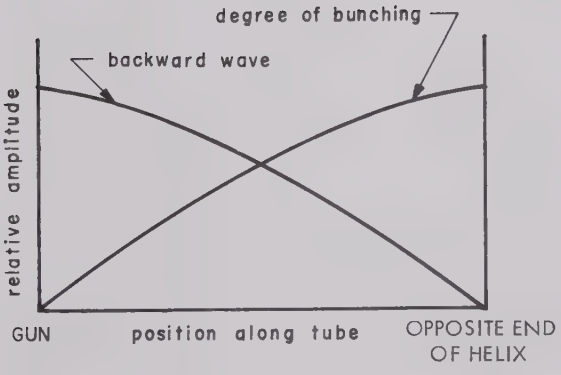
ELECTRON BEAM VELOCITY VS. HELIX-TO-CATHODE VOLTAGE

(B)



ELECTRON DISTRIBUTION

(C)



RELATIVE AMPLITUDE VS. POSITION ALONG TUBE

(D)

FIGURE 4-2. OPERATING CHARACTERISTICS OF BWO TUBE

output signal during any portion of the band, indicating that the output signal is totally or partially unleveled, is sufficient to allow the UNLEVELED light to glow.

The signal level applied to the leveler-amplifier from the internal or external detectors is adjustable with individual SENSITIVITY controls to provide optimum response in the leveled loop.

4.2 THE BACKWARD WAVE OSCILLATOR TUBE (See Figure 4-1).

The backward-wave oscillator (BWO) tube is a voltage-tunable microwave oscillator vacuum tube. It consists of an electron gun, a slow wave structure (helix), and an ion collector at the far end of the slow wave structure. The helix collects all electron current in the tube since there is no electron collecting electrode at the target end of the tube. The ion collector electrode, internally connected to the cathode, is provided to collect positive ions and establish a field gradient that drives the electron current outward for interception by the helix. The rf output of the tube is produced by the interaction between the electron beam passing from the gun to the opposite end and the electromagnetic field of a microwave signal developed on the helix.

Surrounding the evacuated envelope of the tube is a cylindrical permanent magnet which produces a strong axial field. This field focuses the electrons in the beam and allows movement only in the direction of the axis of the tube. An exterior housing completely covers the magnet and tube, and no magnet adjustments are possible. The tube electrodes are connected to wire leads which are brought out through the housing for connection to the Elevated Supply PC Board A12 of the plug-in unit.

The electron gun contains a cathode surrounded by an aperture disc control electrode (the grid), and two screen-type electrodes (the anodes) which accelerate, control, and form the beam. Anode one is brought out to an external connection. Anode two is internally connected to the helix. The heater is a helical coil contained inside the cathode support cylinder.

The emitting portion of the cathode is a hollow cylinder having an L-shaped cross section to absorb the full radiant output of the heater and emit a thin, hollow, cylindrical electron beam having a diameter slightly less than that of the helix. The cold cathode, with a T-shaped cross-section, is fabricated from a non-emitting material and fills the remaining end surface of the cathode cylinder. The grid control field is developed between the grid disc, just outside the hot cathode ring, and the cold cathode which is just inside the hot cathode ring. This provides effective control of the electron beam right at the emitting surface. The anode 1 voltage is maintained at a fixed positive level with respect to the cathode supply, so that the beam emitted from the electron gun does not change appreciably as the cathode voltage is changed to shift the operating frequency. (Since the anodes are of an intercepting type, care must be exercised not to apply too high a voltage or to permit too high a current.)

In a helix backward wave oscillator, it is desirable to have a hollow cylindrical electron beam, since only the electrons that pass adjacent to the helix are fully effective in delivering energy to the wave. Electrons near the middle of the beam consume power but contribute little or nothing to the energy interchange that produces the backward wave oscillations. The electron gun elements are arranged to generate a hollow, circular electron beam. The magnetic field, which restricts the electrons to axial movement, then maintains the same geometry to achieve a hollow cylindrical beam throughout the length of the slow-wave structure.

The helix is a slow-wave structure equal in length to many wavelengths of the lowest output frequency. Thus, the operating frequency range of a particular backward wave oscillator tube is primarily determined by the dimensions of the helix.

It is well known that a slow wave structure will propagate a particular range of frequencies at constant axial velocity (the nondispersive region) and above that range, the axial velocity of propagation increases with frequency (the dispersive region). The backward wave oscillator operates in the dispersive region and it will oscillate at the frequency for which the electron beam velocity is very nearly equal to the axial velocity of propagation of the microwave signal on the helix. Figure 4-2A shows the variation of propagation velocity with frequency for a particular helix, while Figure 4-2B shows how the beam velocity varies with the helix-to-cathode voltage.

From these figures it can be seen why the backward wave oscillator can be voltage tuned. By changing the helix-to-cathode voltage, the electron beam velocity is changed, thereby changing the frequency for which the velocity of propagation on the helix and the velocity of the beam are in synchronism. The helix dimensions, primarily diameter and pitch, are chosen so that the cathode voltage tuning range required for a particular frequency range is reasonable (usually about 200 to 1500 V).

The oscillations, and hence the rf wave, begin in the backward wave oscillator in much the same manner as they begin in other oscillators. Noise waves are established on the helix from the shot noise coupled from the electron beam and from thermal energy developed at the input end of the tube. RF waves are produced which travel in both directions in the helix. Since the desired wave in a backward wave oscillator must travel toward the gun end, the opposite end of the helix is coated with a lossy material to attenuate undesirable waves in the forward direction at that end. These waves will then not be reflected to interfere with desired waves. Amplification of the rf wave is produced by the interaction of the electrons in the beam and the electromagnetic field of the wave.

To obtain this interaction, the electron beam must be at some critical velocity which is achieved by applying a dc voltage to the cathode, thereby establishing a helix-to-cathode voltage appropriate for the desired frequency. The helix remains at ≈ 0 V with respect to ground. Because the rf electromagnetic field is alternating, electrons in the beam are subjected to either an accelerating or decelerating field. Thus, the beam electrons passing axially near the helix experience velocity modulation and form bunches as the beam moves through the helix. The critical areas of interaction are adjacent to the spaces between the helix turns because the axial electric field is strong between helix turns and weak under the turns.

To explain the bunching process, let us examine a group of electrons as they travel from the gun to the opposite end of the tube. Within this group there will be one electron, e, which corresponds to the zero point of the alternating axial field and is therefore unaffected by the signal on the helix. (See Figure 4-2C). This electron experiences no acceleration from the electromagnetic field. However, electron e', just to the left of e, encounters a positive axial field and is accelerated, thus tending to catch up with e. Similarly, electron e", which is just to the right of e, encounters a negative or decelerating field and so slows down and tends to be overtaken by electron e.

The electrons centered about e are thus velocity modulated. This situation is repeated over and over again as the electrons centered about the reference electron pass one space after another enroute from the gun to the lossy end of the helix.

If the helix-to-cathode voltage is set to achieve a beam velocity such that at the lossy end of the helix the phase difference between the wave and bunches in the beam is approximately one-quarter cycle, the electron bunches will encounter relatively strong decelerating fields as they cross the spaces. Thus, the kinetic energy of the electrons is transferred to the backward wave. The amplitude of the backward wave builds up as it progresses toward the gun end of the tube because it passes more and more bunches from which it receives energy. At the same time, the alternating component of the beam current, i.e., the bunching, becomes greater as the electrons progress through the tube, because of the continuing velocity-modulation interaction between the beam and the established backward wave. (See Figure 4-2D).

The rf output signal generated on the helix is coupled off through a dc-blocking capacitor at the gun end, and drives a properly-matched type N or waveguide output connection which operates at chassis ground. The required cathode-to-helix operating potential is obtained by operating the helix near chassis ground and the cathode below ground. To shift the operating frequency approximately one octave from the low to high band limits, an exponential change of cathode supply voltage over a range of about 7:1 is required. The diode shaper board A13 is factory-set to provide the proper tuning voltage range for each tube, within the supply limits of -150 V to -2500V.

The anode is operated at a positive potential with respect to the cathode, and the elevated supply board A12 is factory-set to provide feedback that develops the required output within the supply limits of +30 V to +280 V. The grid is operated at cathode potential for full rf output power, and at -61V or less to cut off the electron beam, thereby turning off the rf output completely. This grid control is used for on-off modulation as well as for power level control in grid leveled units.

Typical cathode current is less than 30 milliamperes, and it divides between the anode and the helix. All beam current not intercepted by the anode thus flows through the helix lead. Helix and anode operating currents are critical operating parameters and must not exceed the power dissipating capability of the tube elements. The helix overcurrent trip-out is set at the maximum allowable helix current for the particular tube used, as indicated in Addendum A enclosed in the envelope bound into the rear of this manual. The maximum allowable anode current, which can easily be monitored with a clip-on milliammeter, is also given in Addendum A. Because of variations in optimum operating currents and distribution of currents between electrodes in BWO tubes of the same type, the rf power output characteristics should be used as the principal indicator of tube performance, but care must be exercised not to exceed voltage and current limits if the tube is still in warranty.

The rf power output is proportional to the beam current. Beam current is controlled by both grid bias and anode voltage, and maximum beam current is limited by the power dissipating capacity of the helix and anode. Grid bias control of power is used in grid leveled units and grid bias on-off control is used in all units (instead of anode control) because the grid is a high impedance (very low current) electrode.

In the "standby" mode when the FREQUENCY Mode Selector switch is turned OFF, the heater, cathode, anode, and helix voltages are maintained, and the grid is biased to cut off the beam. With the other voltages applied, the tube is continuously being outgassed, and it has been found that through this technique, tube life may be extended by more than 10%.

4.3 TUBE PERFORMANCE MONITORING.

Cathode, heater, and anode supply voltages are monitored by means of TP6 through TP9 on the Model 650 chassis, which connect to the supply outputs in that unit. Grid voltage, which is developed in the active stage of the elevated supply PC Board A12 in the plug-in unit, is monitored by TP23 on the left side of the plug-in unit.

Helix current is coupled to terminal 19 of the elevated supply, through the normally-closed contact of FREQ STABILIZING INPUT connector J5. This current is shunted to ground through A12R2, a resistor in the elevated supply, in parallel with A7R14, a 49.9-ohm resistor in the helix overcurrent protection circuit (see Figure 4-10 of the Model 650 Instruction Manual). A12R2 is a factory-selected resistor with a nominal value of 1.5 to 5 ohms. The helix current thus divides between the two resistors, so that a total of between 11 and 34 ma helix current, depending upon tube, is required to produce sufficient current (about 1 ma) across A7R14 to trip the helix overcurrent relay, which also removes the anode voltage. The voltage produced by the helix current flow through these resistors and through series resistor A12R15 (R17 in early units) is monitored at TP22. The series resistor is also factory-selected, so that the monitored voltage will be 10 mv/helix ma.

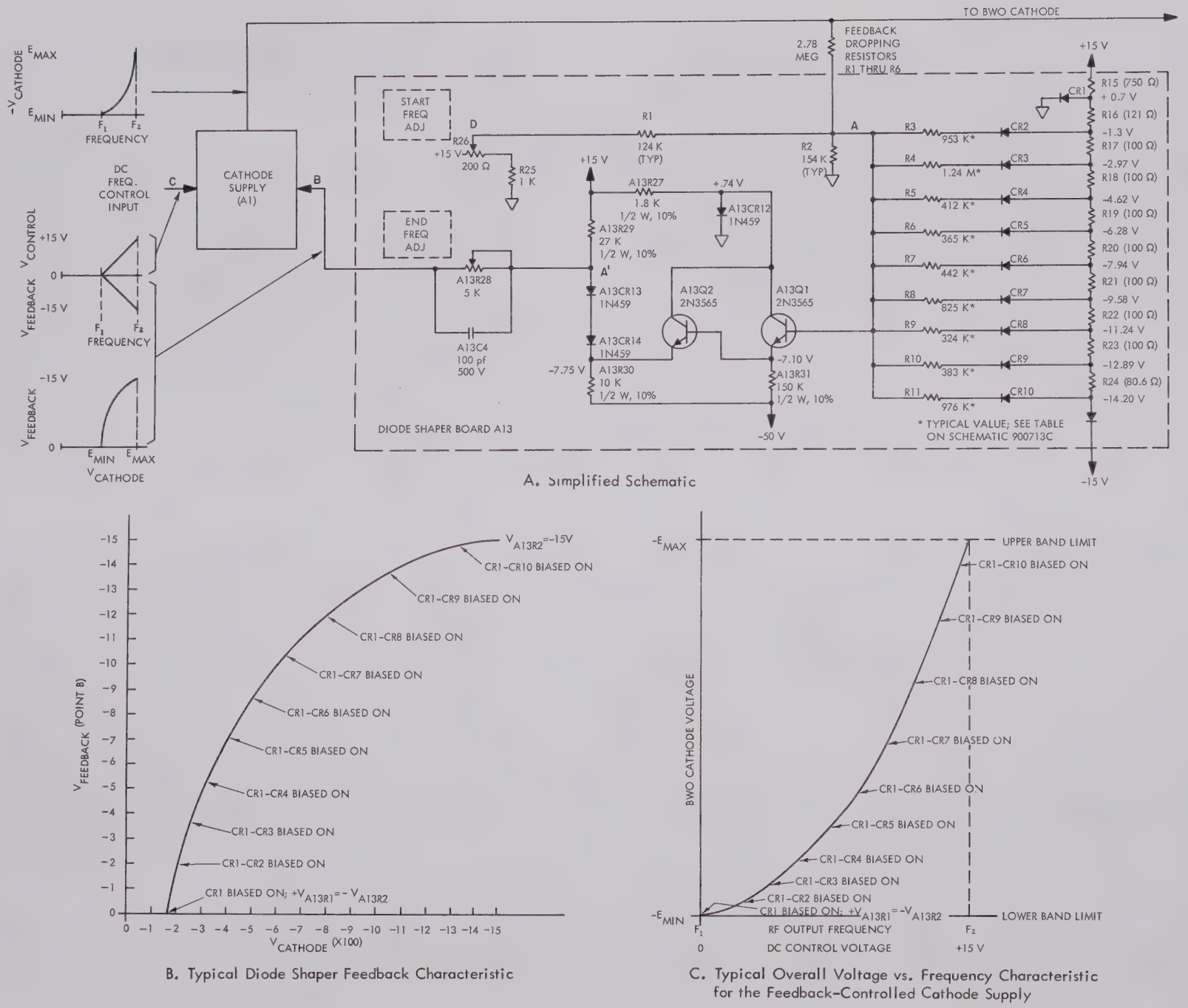
The +100 V supply input to the elevated supply is not used with Varian tubes. TP21 is tied to chassis ground (as indicated by its black color).

4.4 FREQUENCY STABILIZING INPUT.

The FREQUENCY STABILIZING INPUT jack J5 provides a means of applying feedback to the helix to alter the instantaneous helix-to-cathode voltage in single-frequency operation. When generated by a suitable discriminator, such feedback can stabilize the rf single-frequency output to an accuracy approaching that of the best cavity-tuned microwave oscillators. When a mating connector is inserted in J5, it opens the normally-closed contacts shunting R15, so that the applied stabilizing feedback voltage is developed across R15, in series with the helix-to-ground voltage produced by the helix current flow through A12R2 and A7R14. When external stabilization is used, the discriminator voltage applied across R15 ranges between 0 and ±50 V. A positive voltage tends to increase the axial velocity of propagation of the electron beam by reducing the voltage differential between the anode and helix. This tends to increase the oscillation frequency, in accordance with Figure 4-2A. Conversely, a negative voltage tends to decrease the beam velocity and output frequency. The response characteristics are mainly determined by the external feedback discriminator used to generate the stabilizing signal. The discriminator must have a low output impedance in order to supply the required helix current without affecting the voltage stabilization action.

4.5 DIODE SHAPER BOARD (see Figure 4-3).

The diode shaper board provides non-linear feedback as required to produce a tube electron beam velocity which yields frequency output that is linear with sweep time or control



A. Simplified Schematic

B. Typical Diode Shaper Feedback Characteristic

C. Typical Overall Voltage vs. Frequency Characteristic for the Feedback-Controlled Cathode Supply

FIGURE 4-3. SIMPLIFIED SCHEMATIC AND OPERATING CHARACTERISTICS OF DIODE SHAPER BOARD

voltage. The non-linear relationship of frequency to propagation velocity or electron beam velocity, and the resultant requirement for non-linear helix-to-cathode voltage is evident from Figure 4-2A and B. Since the control voltage is linear with sweep time or sweep frequency, the cancelling feedback must be developed in non-linear fashion, so that a non-linear cathode voltage-vs-frequency curve will result when the feedback is used to balance out a linear control voltage.

The diode shaper board provides this non-linear feedback by shunting away an increasing portion of the feedback current through a biased-diode ladder shunt network as the output level increases. This network is biased by a resistor string connected between + and -15 V, such that only one diode is conducting at the lowest supply voltage, and all diodes are conducting at the highest supply voltage, with a non-linear turn-on curve in between. Thus, an increase in the cathode supply voltage produces a feedback voltage increase at a slower rate (negative slope derivative) as shown in Figure 4.3B. Since the cathode supply circuit increases its voltage output until the control and feedback signals applied to its summing junction cancel, this means that a linear increase in control voltage drives the cathode supply output in non-linear fashion with a positive slope derivative, as shown in Figure 4-3C, to produce feedback cancellation.

The resultant cathode supply voltage vs frequency curve produces a linear frequency vs control voltage performance curve. Mathematically, the curve of required cathode supply voltage vs frequency (Figure 4-3C) approximates a third-order exponential function. By establishing a feedback curve that corresponds to the second derivative of that curve, a linear feedback voltage-vs-frequency curve is obtained at point B, since the second derivative of a third-order function is linear.

The feedback voltage supplied to the low-voltage diode shaper board at point A, after passing through dropping resistors R1 through R6, is a fixed fraction of the negative cathode supply output voltage. The feedback voltage developed between point A and ground is produced by the feedback current through A13R2. The ladder network, composed of diodes CR1 through CR10 and R1 through R11, achieves the feedback slope shown in Figure 4-3B by progressively shunting a greater percent of the feedback current away from R2 as the feedback level exceeds the "turn-on" voltage of each biased diode.

Amplifier stages Q1 and Q2 are emitter-follower stages that serve as an impedance converter amplifier to provide a low-impedance output at point B with the same voltage as the feedback level at point A. The point B output then serves as a suitable low-impedance source for summing junction feedback current through summing resistors A1R6 and A1R38 in the cathode supply.

Resistors A13R15 through A13R24 and diode A13CR11 establish the bias on the diode string, and are the same value in all shaper boards. Diode A13CR1 stabilizes the voltage at the junction of R15 and R16 as the current load changes during feedback shunting conditions. Resistors A13R1 through A13R11 are different for each plug-in unit model, and are selected to obtain the desired curve by shunting away a greater percent of the increasing feedback current as the feedback voltage level reaches the forward-biasing point for each diode. The overall effect is that the feedback voltage developed at point A rises as cathode voltage increases, but at a slower rate, because resistors A13R3 through A13R11 shunt away part of the current that would otherwise pass through A13R2 to develop feedback voltage between point A and ground.

The resultant feedback voltage curve (Figure 4-3B) is a smooth-curve approximation with nine (9) gradual slope changes as the feedback level reaches the turn-on points of A13CR2 through A13CR10. The decrease in slope at each turn-on point is related to the additional shunting effect of the individual resistance values of A13R3 through A13R11 and the net difference between the level at point A and the return voltage of each diode.

At the low band-edge output frequency, the cathode supply output voltage must have a negative value corresponding to the minimum bias requirement of the tube, while the control voltage is zero. Thus, a zero feedback voltage must be developed at a finite supply output level, as shown by the X-axis intercept of the curve in Figure 4-3B. This is accomplished by selecting the value of A13R1 and setting its return voltage (point D) at a positive level between 12.5 and 15 V by means of Start Frequency Adjust resistor A13R26. This positive offset circuit then biases point A positively until the cathode supply voltage increases to the point where the cathode supply feedback voltage supplied to point A equals the positive offset voltage. This establishes a 0-volt null at point A, as required for zero feedback voltage. As the control voltage is subsequently increased above 0 to +15 V, the feedback developed at point A increases non-linearly from 0 to -15 V.

The dc impedance converter amplifier (A13Q1 and A13Q2) consists of two cascaded emitter follower stages with the collectors held close to ground level by A13CR12. Diodes A13CR13 and A13CR14 compensate for the sum of the emitter-base drops in A13Q1 and A13Q2 when these transistors are biased to heavy conduction by a 0-level feedback signal at point A, thus developing a 0-level signal at point A'. As the feedback signal increases to the -15 V level, the conduction of A13Q1 and A13Q2 decreases so that the voltage at A' tracks that at point A, but has a higher source impedance to drive the summing junction.

The End Frequency Adjust resistor A13R28 provides an adjustment for the feedback current supplied from the diode shaper board to summing resistor A1R6 in the cathode supply. It can be used to adjust the overall slope of the diode shaper board curve by establishing the feedback level required to generate 1 ma feedback current to the summing junction at the upper band limit. This then sets the maximum cathode supply voltage limit corresponding to that required by the BWO tube for the upper band-limiting frequency. When the BWO tube is replaced, adjustment of A13R1 and A13R28 permits the feedback of the diode shaper board to be tailored to the characteristic of the new tube without requiring replacement of fixed resistors on the diode shaper board.

4.6 LEVELER AMPLIFIER (see Figure 4-4).

4.6.1 GENERAL. The leveler-amplifier operates as a closed-loop differential error signal amplifier driving the grid of the BWO tube (via the transfer oscillator) to correct for differences between the control and sampler signal levels applied to the differential input stage through A11-B and A11-C. The leveler amplifier consists of a differential amplifier stage (A11Q1) followed by two emitter-follower stages (A11Q2

and A11Q3). There is also a single-stage amplifier (A11Q4) which drives the UNLEVELED WHEN LIT lamp.

With RF OUTPUT switch S2 in the LEVELED mode, the leveler amplifier receives an input signal through terminal A11-B from the rf sampler crystal detector, to drive one side of A11Q1. On units with an internal sampler, RF SAMPLER switch S1 selects either the internal or external sampler to drive the leveler amplifier. The rf sampler signal has an amplitude of at least -60 mv at a level corresponding to the maximum power available with full-band leveling.

The signal from the leveler reference output of the modulator is tapped from the POWER LEVEL control resistor R10 and applied through A11-C to the other side of dual transistor A11Q1. The signal level at R10 has a maximum amplitude of -300 mv corresponding to unmodulated output, and an amplitude of 0 V corresponding to "full off" modulation. With unmodulated output, the POWER LEVEL control R10 adjusts the level applied to A11-C between 300 mv and a minimum level set by the Minimum Power Level control R11, which is connected between R10 and ground. Adjustment of R11 sets the minimum level of the output provided by R10 between -60 mv and 0 mv.

The nominal minimum setting of about -20 mv corresponds to a square-law sampler output level 5 db below the nominal -60 mv which corresponds to the full-band-leveled power point. The maximum setting of -300 mv corresponds to sampler output of up to 7 db above the full-band-leveling point, to permit partial-band leveling at higher power levels in accordance with the tube characteristic.

4.6.2 LEVELER-AMPLIFIER OPERATION. If the level applied to A11-C is more negative than that supplied to A11-B, a condition of "insufficient rf output power" is indicated. In that case the relatively greater forward bias on the left half of A11Q1 causes it to conduct more heavily and take control of the differential stage. The result is that the base of A11Q2 is driven close to +15 V, reducing its conduction. The reduced conduction of A11Q2 isolates the base of A11Q3 from +15 V, thereby dropping the applied base voltage at that transistor and reducing its conduction. The result is a drop in the positive output signal supplied to the transfer oscillator through A11-E. This reduced control signal reduces the amplitude of the grid driver output from the transfer oscillator. The reduced-amplitude driver output reduces the negative bias applied to the grid by the active modulator stage A12Q1 in the elevated supply, thereby increasing the rf power output from the BWO tube.

If the level applied to A11-B is more negative than that applied to A11-C, indicating "excessive output power," the amplifier stages respond in an opposite manner to increase the conduction of A11Q3 and thereby increase the positive output signal supplied to the modulator through A11-E. This increases the drive signal output of the transfer oscillator to increase the negative grid bias developed by A12Q1 in the elevated supply, thereby reducing the rf power output from the BWO tube.

In the LEVELED position of S2, the input to A11-B is obtained from either an external or internal sampler (as applicable), to provide the closed-loop level control operation described above. In the UNLEVELED position of S2, A11-B is connected to the +15 V supply through 100 K resistor R7. This assures that the base of the left half of Q2 is biased more positively than the base of the right half, a condition equivalent to the "insufficient output power" condition in the leveled mode. As a result, regardless of the setting of POWER LEVEL control R10, the right half of A11Q1 conducts only slightly, and A11Q3 is thereby biased to minimum conduction so that the output signal supplied to the modulator through A11-E is at 0 V.

Amplifier response is stabilized by a feedback loop consisting of A11C3 and A11R6 around the A11Q2 stage. Diode A11CR1 establishes a negative feedback path between the emitter-follower output resistor string in the A11Q3 stage and the base of the left half of A11Q1. This feedback limits the drop across A11R11 and prevents the output at terminal E from going more positive than +11V, thereby avoiding saturation of both the leveler and transfer oscillator. The A11CR1 feedback loop stabilizes leveler response when square-wave modulation is used by smoothing the delay interval between the modulator reference signal amplitude change at A11-C and the subsequent sampler signal change at A11-B. It permits the leveler to maintain control of the "power on" signal envelope without interfering with individual cycles of the square-wave modulation.

This feedback does not significantly degrade the leveling performance for the modulated signal envelope or for unmodulated CW signals, since level variations in such signals occur at a rate at least an order-of-magnitude slower than the rise and fall time of the square-wave modulation.

Diode A11CR2 prevents the output from going more negative than -1V, since the transfer oscillator Diode A11CR2 works only with positive signals. The leveler amplifier frequency response is set by the R-C bypass network A11C3-A11R6. This network prevents leveler oscillation by controlling the high-frequency gain and phase response.

4.6.3 UNLEVELED LIGHT OPERATION. Transistor A11Q4 controls the UNLEVELED WHEN LIT lamp DS1. This lamp is lit when +100 V is applied to it through A11R13. When S2 is in the UNLEVELED position, the output signal developed at A11-E is 0 V, as described above. In this case A11Q4 is held cut off, and DS1 is lighted. When the output signal at A11-E is continuously above 0 V, indicating that controlled leveling performance is taking place throughout the range being swept, the positive signal biases A11Q4 to conduction. A11Q4 then couples A11-H to ground and extinguishes DS1. If leveled performance is obtained over just a fraction of the range being swept, A11Q4 is turned on and off, and the capacitance of DS1 stabilizes the voltage at A11-H at a level that keeps DS1 lit.

4.7 ELEVATED SUPPLY

The passive circuits of the elevated supply PC Board A12 are illustrated and discussed individually in the paragraphs covering related circuits in the main chassis, in Section 4 of the Model 650 Instruction Manual.

The grid modulator A12Q1 is the only active stage in the elevated supply. Operating in the common-base configuration, it acts as an impedance converter and isolator for the output drive current developed by the transfer oscillator driver stage A9Q4.

After passing through A12Q1 the drive current develops the necessary grid bias across A12R4 and A12R5 to operate the grid at a voltage negative with respect to the cathode (0 line). For tube cut-off, a maximum driver/modulator current of 35 ma produces the necessary cut-off bias of -61V at A12-14. If a particular tube requires much lower drive voltage, this is achieved by connecting the grid to A12-13 (for -27 V drive) or by interchanging A12R4 and A12R5 and connecting the grid to A12-13 (for -37 V drive). Such changes, when made, are noted on the Addendum A sheet. Diode A12CR1 prevents the grid from ever being driven positive with respect to the cathode.

4.8 ANODE PROTECTION CIRCUIT

Varian BWO tubes contain a mesh-type intercepting anode (see Figure 4-1). The power dissipation of this delicate anode electrode must not be allowed to exceed specified ratings. To protect against excess dissipation, an anode protection circuit (A19) Part No. 951619 is installed in plug-in units containing Varian tubes. This circuit is connected as shown in overall schematic 900774C. It completes the connection between A12-4 and A12-5 to couple the anode supply voltage from P7-1 through to the BWO anode. (Plug-in units not containing the anode protection circuit have a shunt wire connecting A12-4 and A12-5 in the elevated supply.)

The anode protection circuit is set to "trip" when the current approaches 90% of the maximum anode current specified by the tube manufacturer. (This is well above the current level required for rated power output.) The Actual Trip-out factory setting is specified in addendum A. When such an anode overcurrent condition occurs, the anode protection circuit "trips" and connects the anode voltage through a small resistance to the 0-line (which is tied to the BWO cathode). This eliminates the BWO anode-to-cathode positive bias to protect the tube and also triggers a trip-out of the high voltage supply protective circuits. Thus, the trip-out will be indicated by the turn-off of the HIGH VOLTAGE ON lamp on the front panel. After the problem is corrected, operation can be restored by pressing the RESET button.

The anode protection circuit operates as follows (see schematic B907307): The anode current drawn by the anode (A19-3) from the anode supply (A19-1) creates a voltage drop across A19R2, which is partially shunted by its own wiper. A19CR1 provides compensation for the V_{be} drop in sensing transistor A19Q1. The A19R2 wiper is set so that A19Q1 will be turned on by the voltage developed across A19R2 when the desired trip-out current level is reached. As long as A19Q1 is off, there will be approximately equal current through A19R4 and A19R5, so that no forward bias will be applied to A19Q2, keeping it cut off. As long as A19Q2 is cut off, no gate trigger current will be available for silicon-controlled rectifier (SCR) A19Q3, and it will remain gated off.

When A19Q1 senses an overcurrent condition and turns on, the increased current flow through A19R4 provides turn-on bias to A19Q2. A19Q2 turns on and provides gate trigger current to SCR A19Q3. A19Q3 then is gated on and ties the anode supply to the 0-line (and cathode) through A19R7 to immediately shunt the excess current away from the anode. The drop established by this current flow through A19CR2 and A19CR3 biases A19Q4 to conduction. A19Q4 then couples a signal slightly more positive than cathode voltage level to the lamp in A6V1, via P7-2. This energizes the lamp as though it were energized by A6K1 (which would connect the same point to the HTR (+) which is tied to the cathode).

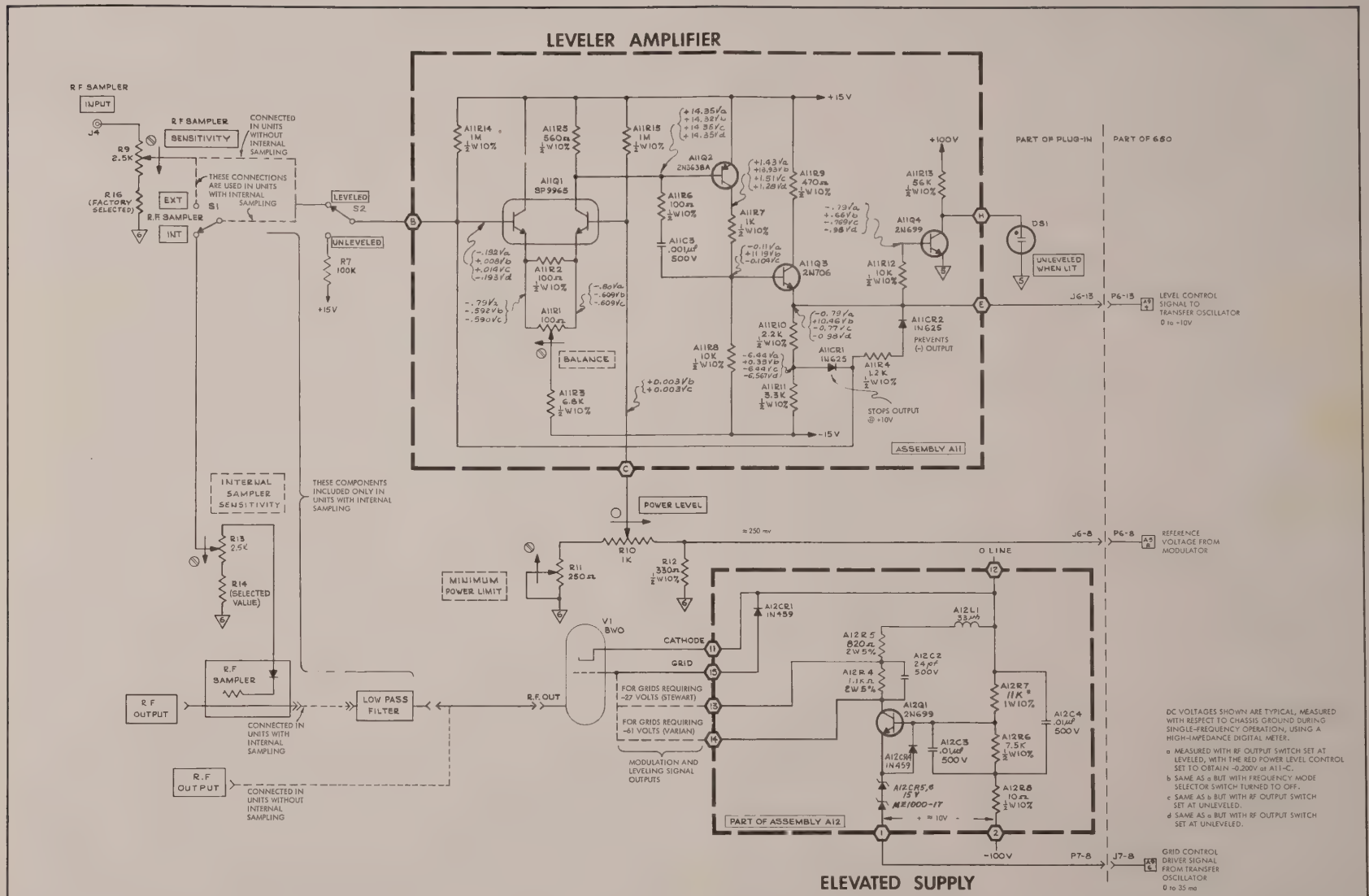
The lamp then triggers the light-sensitive resistor in A6V1 to turn on protection relay K2 which turns off the high voltage supplies in the instrument. Turn-off of the high voltage supplies removes power from the anode protection circuit, so it will automatically reset (if the overcurrent condition is removed) when high voltage is restored by pressing the RESET button or by normal turn-on of the line power switch.

4.9 LOW PASS FILTER (Units Below 12.4 GHz)

Most plug-in unit models with an internal sampler contain a low-pass filter as the first element in the rf output line from the BWO tube. This filter is a transmission-type resonant structure which attenuates rf harmonics generated by the BWO tube. Plug-in units without an internal sampler (i.e. without the "K" model number suffix) do not contain a low pass filter unless they contain a Varian tube model having an internal filter (see Table 1-1). When external leveling is desired on instruments not having a filter, it may be necessary to add a low-pass filter externally between the RF OUTPUT jack and the external sampler to improve leveling performance. Harmonic output without the filter will be at least 20 db down, but still may generate enough "noise" voltage at the crystal detector to degrade leveling performance at the upper end of some frequency bands.

4.10 FLAP ATTENUATOR (Units Above 12.4 GHz)

The flap attenuator (supplied on units without internal sampling) is the final element in the rf output line, and its output port serves as the RF OUTPUT connection. This attenuator consists of a waveguide section with an attenuation plate (flap) which is parallel to the short dimension of the guide, and is moved into and out of the guide through a longitudinal slot in the center of the top waveguide wall. The flap is controlled by a gear driven by the black POWER LEVEL control knob shaft.



650-1, -3, -5

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FIGURE 4-4
SIMPLIFIED SCHEMATIC OF PLUG-IN UNIT

SECTION 5 - MAINTENANCE

NOTE: Main paragraph topics in this section are numbered to agree with similar paragraphs in the Model 650 Instruction Manual. The material in this section should be used in conjunction with the Maintenance Section (Section 5) of the Model 650 Instruction Manual, which contains material pertinent to all plug-in units. This manual contains supplementary material pertinent to the plug-in "family" covered by this manual.

5.1 PERIODIC MAINTENANCE

Refer to Model 650 Instruction Manual.

5.2 VOLTAGE AND CURRENT MEASUREMENTS AT CHASSIS TEST POINTS.

WARNING

The voltages and current pickoffs pertaining to the plug-in unit, available at test points on the left side of the Model 650 chassis and the plug-in unit, are at high-voltage levels. Suitable high-voltage measurement techniques and precautions must be used. The cathode supply output (TP6) is measured with respect to chassis ground, and a high-voltage voltmeter or a high-voltage probe must be used. For all other high voltage measurements, the "0 line" (TP10) which is at or near cathode potential is the reference rather than chassis ground, and a floating voltmeter with at least 3000 volts insulation must be used. The heater supply output between TP7 and TP8 may be measured with high voltage off, using a standard meter. The lowest cathode supply output voltage, which in some plug-in units is low enough for measurement without an insulated meter, is obtained with a single frequency setting at the low end of the band. Other high voltage measurements should be made at this setting of the cathode supply to keep the "0 line" voltage as low as possible for safety reasons.

a. Cathode Supply Voltage. [TP6 (-) to chassis ground (+)]. The proper cathode supply output voltages for the lower and upper band limit frequencies, corresponding to single-frequency settings of 0 and 100 on the logging scale, are given in Addendum A in the envelope at the rear of this manual. When a replacement BWO tube has been installed, refer instead to the manufacturer's data sheet for the tube, which should be in the same envelope. Make the dc voltage measurement with a high voltage digital meter or a suitable voltage-divider probe. Refer to Paragraph 5.3.4 of this manual for measurement of ripple effects.

b. Heater Voltage. [TP7 (+) to TP8 (-)]. All Varian BWO tubes utilize less than 1.5 amperes heater current, so that the proper heater voltage with one of these plug-in units loading the supply is 6.3 V ± 0.1 V. It is recommended that this voltage be measured with the high voltage turned off by removing the top or rear panel to defeat the interlock switch. If the measurement is made with high voltage on, the heater will be at cathode potential, and a floating insulated voltmeter must be used.

c. -100 V Supply. [TP10 (+) to TP11 (-)]. Voltage should be 100 ± 0.1 V. For this measurement, the instrument must be operating with the FREQUENCY Mode Selector switch set to SINGLE, and with no modulation applied. The measurement must be made using a floating, insulated voltmeter.

d. Anode Supply. [TP9 (+) to TP10 (-)]. The proper anode supply voltage output setting is given in Addendum A in the envelope at the rear of this manual. When a replacement BWO tube has been installed, refer instead to the manufacturer's data sheet for the tube, which should be in the same envelope. The measurement must be made using a floating, insulated voltmeter.

e. Grid Voltage. [TP10 (+) to TP23 (-)]. Voltage should be ≈ 0V with controls set for RF ON (unmodulated); and 61 ± 10 V (or less if noted on Addendum A) with the FREQUENCY Mode Selector switch in the OFF position. The measurement must be made using a floating, insulated voltmeter.

f. Collector Current. Collector current cannot be measured on Varian BWO tubes. All beam current is intercepted by the helix. The "Collector Current" test point (TP21) on these plug-in units is connected to chassis ground.

g. Helix Current. [TP22 (-), TP21 or chassis ground (+)]. The proper helix currents in ma for the lower and upper band limit frequencies, corresponding to single-frequency settings of 0 and 100 on the logging scale, are given in Addendum A in the envelope at the rear of this manual. When a replacement tube has been installed, refer instead to the data sheet for the new tube, which should be in the same envelope.

To measure the helix current, measure the voltage drop between TP22 and TP21 (or chassis ground) with the controls set for RF ON (unmodulated). This is the voltage drop produced across a 10-ohm resistance by the helix current. Hence, the voltages measured in millivolts must be divided by 10 to obtain the current in milliamperes. This voltage measurement is at ground level so that a floating or high voltage voltmeter need not be used.

NOTE: The helix overcurrent trip-out level is listed in Addendum A.

h. Anode Current. The maximum allowable anode current and voltage are listed in Addendum A. On units having an anode protection circuit, the current trip-out level is indicated on Addendum A. Operating current level is typically well below the maximum value. To measure the anode current, use a clip-on milliammeter to monitor current in the red lead which connects to terminal 5 of the Elevated Supply PC Board A12.

WARNING

It will be necessary to remove the instrument top cover and "cheat" the interlock switch to operate the unit with access to the anode lead. Avoid touching the exposed live circuits.

5.3 INTERNAL ADJUSTMENTS.

5.3.1 AVAILABLE ADJUSTMENTS. There are six internal adjustments in each plug-in unit. The instrument is designed for long-term operation with a minimum of adjustment. The main purpose of the adjustments provided is to simplify the recalibration of the plug-in unit after installation of a new BWO tube or other components. These adjustments can also be used for periodic recalibration at six-month intervals or as required. The adjustments and a recommended adjustment procedure for each, are described in the paragraph below. These procedures permit the plug-in unit to be calibrated to meet published specifications, when operating in a Model 650 main chassis which has been factory calibrated or field-calibrated with a Sweep Oscillator Calibration Plug-in unit, Model 650T.

A factory calibration service is available at nominal cost by returning the instrument to ALFRED. Contact your nearest representative or our sales department.

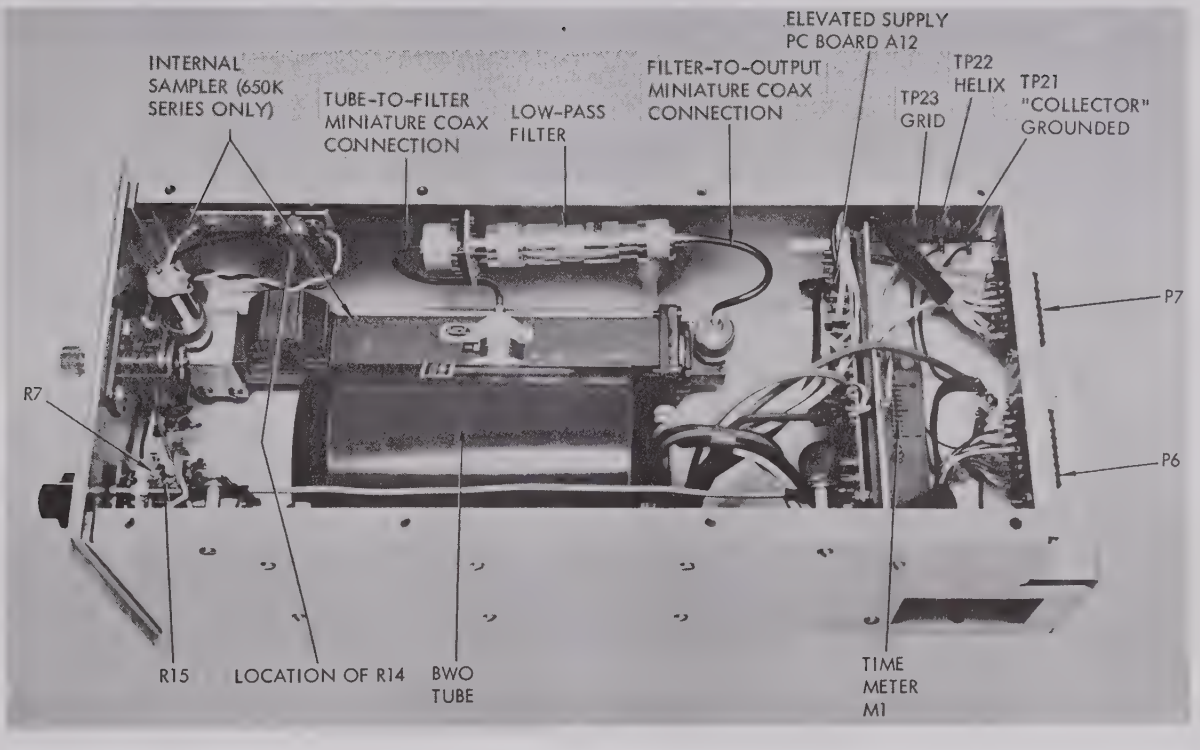


FIGURE 5-1. TOP VIEW OF PLUG-IN UNIT CHASSIS
(UNITS BELOW 12.4 GHz HAVING COAX OUTPUT)

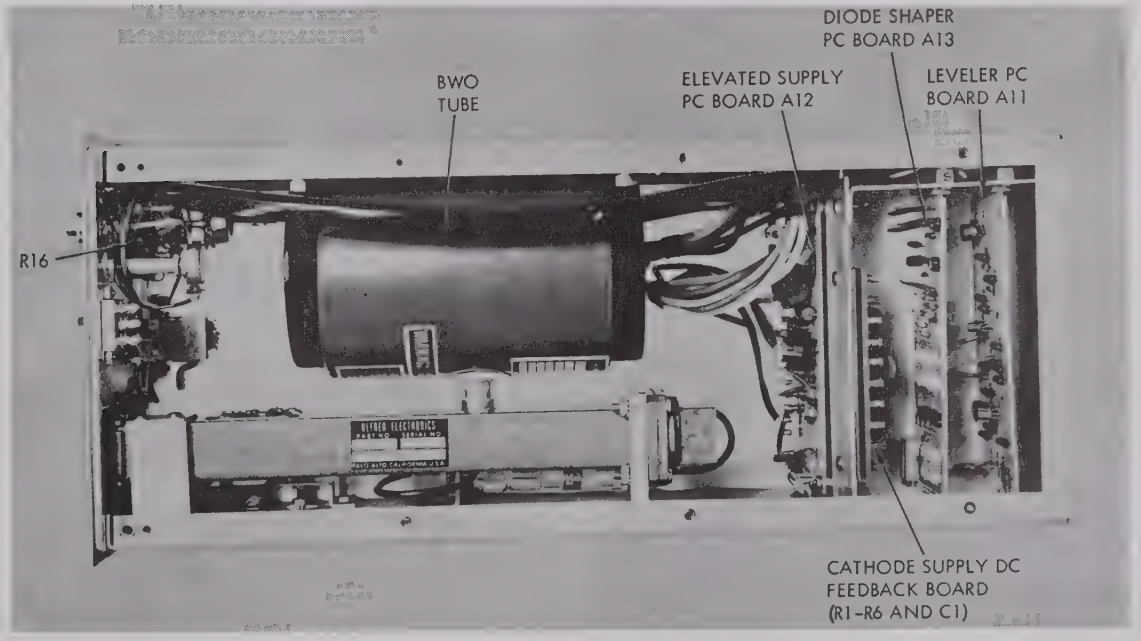


FIGURE 5-2. BOTTOM VIEW OF PLUG-IN UNIT CHASSIS (TYPICAL ALL UNITS)

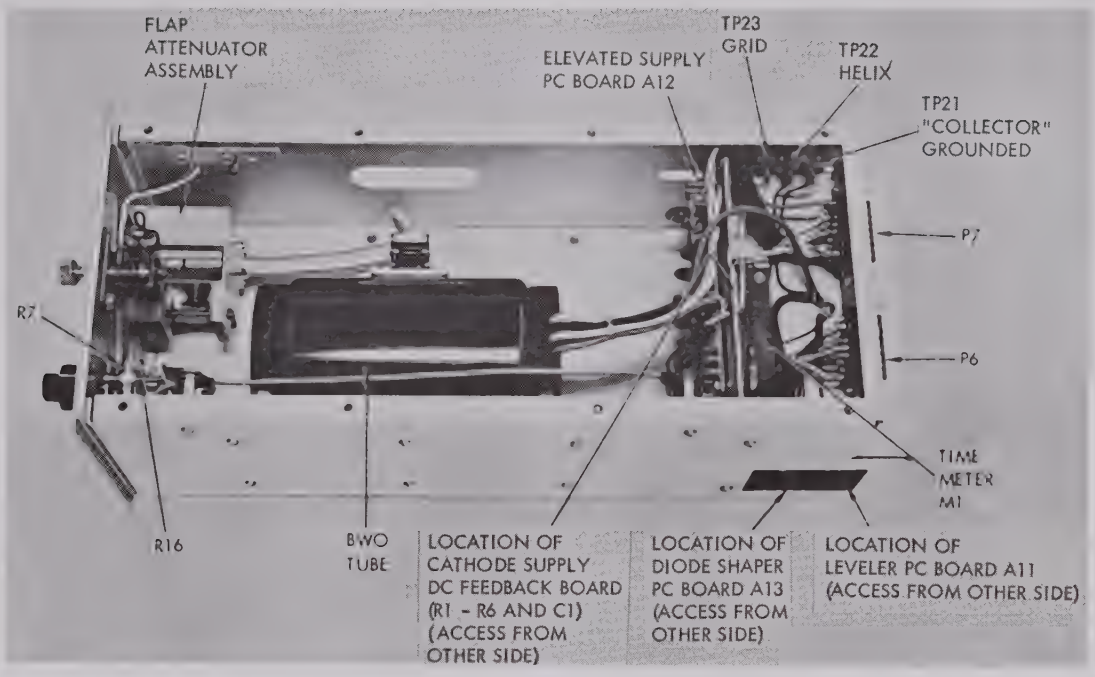


FIGURE 5-2A. TOP VIEW OF PLUG-IN CHASSIS
(UNITS ABOVE 12.4 GHz HAVING WAVEGUIDE OUTPUT)

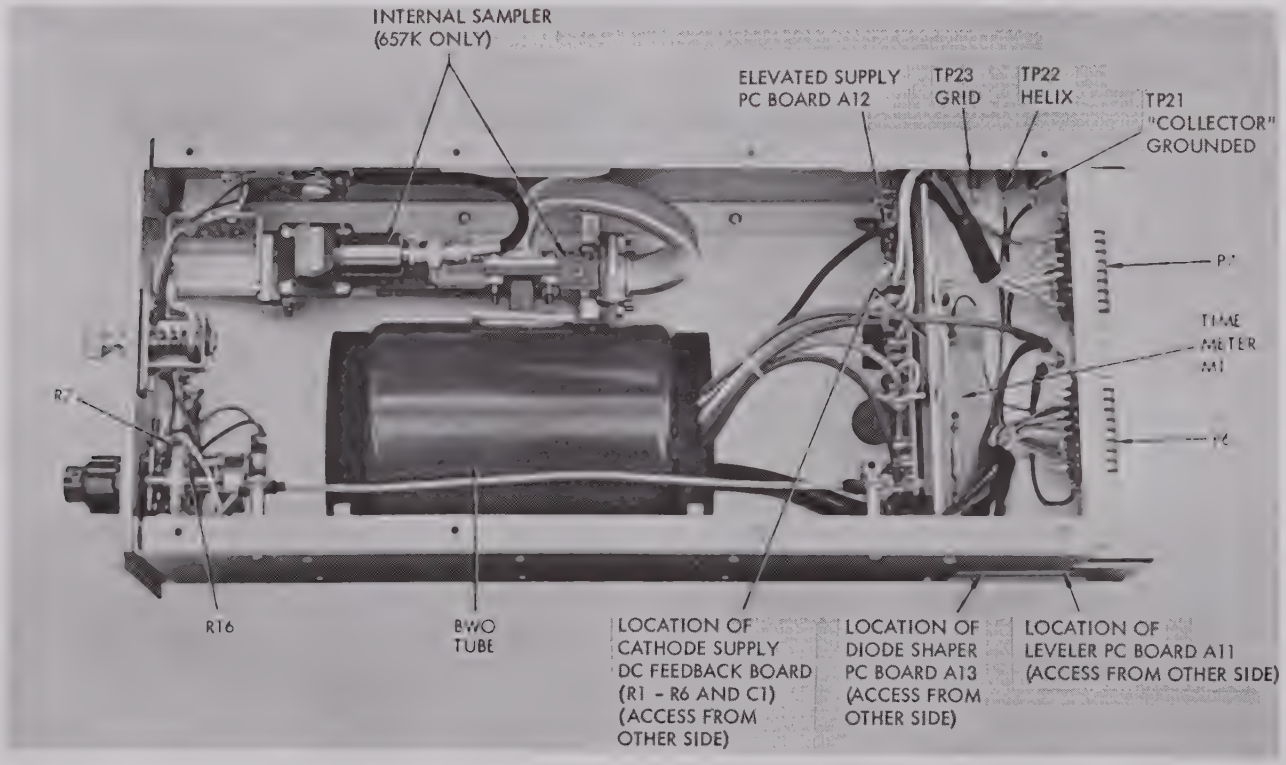


FIGURE 5-2B. TOP VIEW OF MODEL 657K PLUG-IN UNIT
(WITH INTERNAL SAMPLER AND WAVEGUIDE OUTPUT)

NOTE: Refer to the Model 650 Instruction Manual for adjustment procedures for the heater supply voltage (A6R21 HEATER ADJ., Paragraph 5.3.3), the -100 V supply voltage (A6R5 GRID ADJ., Paragraph 5.3.3). These adjustments are accessible from the top of the Model 650 chassis, as shown in Figure 5-1 of the Model 650 Instruction Manual.

5.3.2 ADJUSTMENT PROCEDURES. (All adjustments are shown in Figure 5-2 of the Model 650 Instruction Manual.)

CAUTION

Use a non-metallic screwdriver in making these adjustments. Use of a metallic screwdriver can

(1) Damage magnetic focus of microwave tube
(2) Cause circuit-damaging shorts in the area between the access opening and the adjustment screw.

1. A11R1 LEVELER BALANCE Adjustment. This adjustment is used to balance the base-emitter voltages of the input dual transistor A11Q1. These voltages do not change with age. Unless the factory adjustment is altered improperly, readjustment should be required only when A11Q1 is replaced. At that time, A11R1 should be carefully set to provide a proper balance between the extremes of (1) keeping the UNLEVELED light on improperly when the output is leveled, and (2) obtaining overshoot in the leveled response, particularly at the rf turn-on step function after retrace blanking or during square wave modulation.

   To adjust the LEVELER BALANCE, proceed as follows:

   a. With the plug-in unit installed in a Model 650, make the following control settings:
      FREQUENCY Mode Selector to OFF.
      MODULATION Mode Selector to AM OFF.
      RF OUTPUT to LEVELED.
      (Black POWER LEVEL control, Red POWER LEVEL control and RF SAMPLER INT-EXT switch, where present, can be at any position).
   b. Adjust the LEVELER BALANCE control A11R1 until the UNLEVELED light just goes out.
   c. Connect the RF OUTPUT jack through a suitable attenuator to a detector, and connect the detector output to the vertical channel of an oscilloscope (see Figure 5-3). Use a 47-ohm resistor to terminate the detector cable at the oscilloscope to provide a proper load for the crystal. Use the OUTPUT SWEEP signal to drive the oscilloscope horizontal channel.

   NOTE: On units without internal sampling, connect an external sampler or a directional coupler and detector to drive the SAMPLER INPUT jack. This sampler or coupler should be connected between the RF OUTPUT jack and the attenuator/detector described in Step c above.

   d. Make the following changes in control settings:
      FREQUENCY Mode Selector to SINGLE
      SINGLE Frequency Selector to F_0
      MODULATION Mode Selector to SQ WAVE
      RF SAMPLER switch to INT (if applicable)
      Red POWER LEVEL control to mid-range
      Black POWER LEVEL control* (if present) fully CW
   e. Examine the CRT presentation for excess overshoot on the "rf on" step. Adjust the LEVELER BALANCE control A11R1 slightly, just enough to eliminate any overshoot.

   NOTE: If too much adjustment is made, the square-wave symmetry may be degraded.

   f. Turn the F_0 control to manually sweep the output signal frequency across the band while examining the leveled square wave trace on the CRT for absence of overshoot or poor symmetry. Make a slight re-adjustment of the LEVELER BALANCE control A11R1 if necessary.
   g. Leaving the black POWER LEVEL control* fully CW, turn the red POWER LEVEL control CCW to reduce the output level over a 5-db range below the full-band-leveled point. Again examine the leveled square wave trace on the CRT for absence of overshoot or poor symmetry. Make a slight re-adjustment of the LEVELER BALANCE control A11R1 if necessary.

2. A12R9 ANODE ADJ. Adjustment. This control is used for fine adjustment of the anode voltage supplied to the BWO tube, after installation of the proper-value resistor in the A12R14 circuit position. Re-adjustment will usually be required when the BWO tube is replaced, and may also be useful to restore the power output level of an aging BWO tube. Since the final criteria of a proper anode voltage adjustment (assuming other voltages are correct) is that rated output power is obtained, the final adjustment of anode voltage should be made in terms of output power, in accordance with the procedure given in Paragraph 5.3.5 of this manual. A preliminary adjustment of anode voltage to the operating value specified in the manufacturer's data sheet for a newly installed BWO tube can be made using the following procedure. To check anode voltage in older tubes, use the procedure of Paragraph 5.3.5.

   a. Determine the operating value for anode voltage specified on the manufacturer's data sheet (located in the envelope at the rear of this manual). Use this voltage value and the graph given in Figure 5-8 of the Model 650 Instruction Manual to determine the correct value for feedback resistor A12R14 at the top of the elevated supply PC board in the plug-in unit.
   b. If the value of A12R14 determined in Step a differs from the resistor actually installed in the unit, change A12R14 to the proper value.
   c. Measure the anode voltage between TP9 (+) and TP10 (-), and adjust it to the value determined in Step a, by using A12R9 ANODE ADJ.

   WARNING

   This is a high-voltage measurement. Use a floating, insulated voltmeter.

   d. Refer to Paragraph 5.3.5 for a final adjustment of anode voltage in terms of output power.

3., 4. A13R26 START FREQ and A13R28 END FREQ. Adjustments. These controls are used to set the cathode supply feedback limits to obtain the proper cathode supply output voltage limits for the BWO tube, corresponding to the lower and upper frequency limits of the plug-in unit. The proper voltages for these band limits can be checked as described in Paragraph 5.2 a above.

   Adjustment of these voltages to the prescribed values is the first step in frequency calibration of the plug-in unit. Final frequency calibration involves a further adjustment of A13R26 and A13R28 to obtain calibrated frequency performance. Once final frequency calibration of the plug-in unit has been carried out using the procedure given in Paragraph 5.3.3, these voltages should not be re-adjusted.

   Refer to Paragraph 5.3.3 for the proper adjustment procedure.

* Only on instruments having flap attenuator.

5. R13 INTERNAL SAMPLER SENS. Adjustment (on instrument models with K-suffix numbers only). This control is used to set the signal level applied to the leveler-amplifier from the internal rf sampler. The proper adjustment for standard applications is one that places the full-band-leveling point at the center of the adjustment range of the red POWER LEVEL control, and provides unleveled output with the POWER LEVEL control turned fully CW. This allows the POWER LEVEL control to be set above the full-band-leveled position for higher-level, partial-band leveling, and also provides an adjustment range of at least 5 db below full-band-leveled power when the POWER LEVEL control is turned fully CCW. Note that this control affects only operation with the internal rf sampler. When an external sampler is used, the front panel RF SAMPLER SENS. control provides a similar adjustment function. In achieving a sufficient amount of reduction below the full-band-leveled point, a readjustment of the MINIMUM POWER LIMIT control R11 may also be required.

   The adjustment procedure is as follows:

   a. Connect the RF OUTPUT jack through a suitable attenuator to a crystal detector, and connect the detector output to the vertical channel of an oscilloscope. Use the OUTPUT SWEEP signal to drive the horizontal channel of the oscilloscope.

   b. Make the following control settings:

      RF OUTPUT to LEVELED
      RF SAMPLER to INT
      FREQUENCY Mode Selector to SWEEP $F_1 \rightarrow F_2$
      MARKER AMPLITUDE to OFF
      MODULATION to AM OFF
      SWEEP TIME to .01
      SWEEP TRIGGER to FREE RUN
      F_1 to 0 on the logging scale
      F_2 to 100 on the logging scale
      Red POWER LEVEL fully CW.

   c. Adjust the INTERNAL SAMPLER SENS adjustment until the maximum-power excursion of the unleveled CRT presentation appears flattened, indicating the start of leveled response. Then back off the adjustment so that the unleveled trace remains unaffected with the red POWER LEVEL control remaining fully CW.

   d. Turn the red POWER LEVEL control CCW slowly and observe the onset of leveled performance across the band. Full-band leveling should be achieved at a mid-range setting of the POWER LEVEL control.

   e. With the red POWER LEVEL control set at the maximum power level that allows full-band-leveling, adjust the oscilloscope vertical amplification to obtain a full-height presentation on the CRT.

   f. Turn the red POWER LEVEL control fully CCW. With the oscilloscope amplification set as above, and the input to the crystal detector attenuated sufficiently that square-law operation is assured, the presentation on the CRT should be reduced to less than 1/3 of the amplitude observed in Step e. If not, adjust the MINIMUM POWER LIMIT adjustment R11 to achieve such a reduction in level.

6. R11 MINIMUM POWER LIMIT Adjustment. This control is used to set the range of the red POWER LEVEL control by adjusting its lower limit. It does not affect the upper limit of the control range.

   The adjustment procedure for units with internal sampling is included as the final step in the INTERNAL SAMPLER SENS adjustment procedure, item 5 above. For units without internal sampling, use the following procedure:

   a. Connect a suitable external sampler loop, consisting of a sampler or a directional coupler and detector, to the RF OUTPUT jack, and use the sampler output to drive the RF SAMPLER INPUT jack (see Figure 5-3). Terminate the rf loop with a suitable attenuator and crystal detector, and connect the detector output to the vertical channel of an oscilloscope. Use the OUTPUT SWEEP signal to drive the horizontal channel of the oscilloscope.

   b. Make the following control settings:
      RF OUTPUT to LEVELED
      RF SAMPLER to EXT
      FREQUENCY Mode Selector to SWEEP $F_1 \rightarrow F_2$
      MARKER AMPLITUDE to OFF
      MODULATION to AM OFF
      SWEEP TIME to .01
      F_1 to 0 on the logging scale
      F_2 to 100 on the logging scale
      Red POWER LEVEL fully CW
      Black POWER LEVEL* fully CW

   c. Adjust the front panel RF SAMPLER SENS control until the maximum-power excursion of the unleveled CRT presentation appears flattened, indicating the start of leveled response. Then back off the adjustment so that the unleveled trace remains unaffected with the red POWER LEVEL control remaining fully CW.

   d. Turn the red POWER LEVEL control CCW slowly and observe the onset of leveled performance across the band. Full-band leveling should be achieved at a mid-range setting of the red POWER LEVEL control.

   e. With the red POWER LEVEL control set at the maximum power level that allows full-band-leveling, adjust the oscilloscope vertical amplification to obtain a full-height presentation on the CRT.

   f. Turn the red POWER LEVEL control fully CCW. With the oscilloscope amplification set as above, and the input to the crystal detector attenuated sufficiently that square-law operation is assured, the presentation on the CRT should be reduced to less than 1/3 of the amplitude observed in Step e. If not, adjust the MINIMUM POWER LIMIT adjustment R11 to achieve such a reduction in level.

* Only on instruments having flap attenuator.

5.3.3 FREQUENCY CALIBRATION ADJUSTMENT. (See Figure 5-3.)

The following procedure should be used for periodic frequency calibration of the plug-in unit.

CAUTION

Check all supply voltages except the cathode supply output before performing this calibration adjustment. (See Paragraph 5.2.)

a. Let the instrument warm up and stabilize for about 1/2 hour.

b. Make the following control settings:

RF OUTPUT to UNLEVELED
FREQUENCY Mode Selector to SINGLE
SINGLE Frequency Selector to F_0
MARKER AMPLITUDE to OFF
MODULATION to AM OFF
SWEEP TIME to .01
SWEEP TRIGGER to FREE RUN

c. With the instrument operating unmodulated in single-frequency mode, measure the cathode supply voltage output at the lower and upper band limit frequencies as directed in Paragraph 5.2 a.

d. If either voltage measured in Step c is incorrect, adjust it to the proper value using the START FREQ or END FREQ adjustment controls. (The START FREQ adjustment sets the voltage at the low band-edge frequency, and the END FREQ adjustment sets the voltage at the high band-edge frequency.)

e. Connect an rf test loop consisting of a variable attenuator, wavemeter, and crystal detector to the RF OUTPUT jack, and connect the crystal detector output to the vertical channel input of an oscilloscope. Use the OUTPUT SWEEP signal to drive the horizontal channel of the oscilloscope.

f. Make the following changes in control settings:

FREQUENCY Mode Selector to SWEEP $F_0 \pm \Delta F$
RETRACE to OFF
ΔF AMPLITUDE fully CW
SWEEP TIME to .01
SWEEP TRIGGER to FREE RUN
F_0 to 0 on the logging scale (the low band-edge frequency).

g. Adjust the wavemeter to the low band-edge dial frequency.

h. Observe the CRT presentation. The wavemeter pip should appear exactly in the center of the trace. If it is obviously off-center, adjust the START FREQ control to move the pip to the center of the trace.

i. When the pip appears centered in Step h above, turn the ΔF AMPLITUDE control CCW slowly, continuing to the CCW rotation limit (labeled OFF) unless the pip appears off center as the control is turned. If necessary, stop turning the ΔF AMPLITUDE control, and adjust the START FREQ control again to restore the pip to the center of the trace. Continue this procedure until the ΔF AMPLITUDE control is fully CCW and the wavemeter pip remains in the center of the trace.

j. Adjust the wavemeter to the high band-edge dial frequency.

k. Adjust the F_0 FREQUENCY control to 100 on the logging scale, and turn the ΔF AMPLITUDE control fully CW.

l. Observe the CRT presentation. The wavemeter pip should appear exactly in the center of the trace. If it is obviously off-center, adjust the END FREQ control to move the pip to the center of the trace.

m. When the pip appears centered in Step k above, turn the ΔF AMPLITUDE control CCW slowly, continuing to the CW rotation limit (labeled OFF) unless the pip appears off center as the control is turned. If necessary, stop turning the ΔF AMPLITUDE control, and adjust the END FREQ control again, to restore the pip to the center of the trace. Continue this procedure until the ΔF AMPLITUDE control is fully CCW and the wavemeter pip remains in the center of the trace.

n. Adjust the F_0 FREQUENCY control to 0 on the logging scale and turn the ΔF AMPLITUDE control fully CW.

o. Repeat Steps g through m.

p. Repeat Steps n and o one additional time. Repeating the steps is necessary because of the interaction of the START FREQ adjustment A13R26 and END FREQ adjustment A13R28.

q. Check the frequency tracking across the dial at several points by turning the ΔF AMPLITUDE control to MAX and setting both the F_0 control and the wavemeter to identical frequencies. Frequency accuracy should be $\pm$ 1.0 % or better across the band. If necessary, Steps g through p above may be repeated to offset the end frequencies slightly in order to reduce mid-band inaccuracies.

r. If it is desired to check residual FM and AM, retain the test set-up and follow the procedures of Paragraph 5.3.4.

5.3.4 CHECKOUT PROCEDURE FOR RESIDUAL FM AND AM. (See Figure 5-3.)

The following procedure may be used for periodic verification that residual FM and AM are within specification limits. It should be performed as a continuation of the frequency calibration adjustment procedure given in Paragraph 5.3.3 above. The FM procedure should be performed at the low-frequency end of the band, because residual FM effects are greatest at that point; and the AM procedure should be performed at the high-frequency end of the band.

a. The instrument should be operating with an rf test loop equivalent to Step e of Paragraph 5.3.3. To permit the high sensitivity readings required later in the procedure, the oscilloscope should be set for AC coupling.

b. Make control settings as in Step f of Paragraph 5.3.3, except turn the RETRACE control to ON. Also set the RF OUTPUT control to UNLEVELED and turn the MARKER AMPLITUDE and MODULATION both off.

c. Adjust the wavemeter to center its pip on the CRT display.

d. Slowly turn the ΔF AMPLITUDE control CCW, while adjusting the wavemeter slightly, as necessary to keep the wavemeter pip centered on the CRT trace. Continue this procedure until the ΔF AMPLITUDE control is fully CCW.

e. Set the wavemeter to place one-half of its pip at the left edge of the trace.

f. Adjust the oscilloscope horizontal sensitivity to yield a full-graticule sweep width while being driven by the OUTPUT SWEEP signal of the Model 650.

g. Adjust the oscilloscope for maximum vertical sensitivity, and set the vertical position so that the CRT presentation shows a sloping line which represents one half of the magnified wavemeter pip at the left edge.

h. Adjust the wavemeter enough to move the sloping line (pip) from one edge of the CRT presentation to the other. The difference between the wavemeter settings at each edge of the trace will calibrate the horizontal scale (typical value = 20 mc).

NOTE: Since the rf output is being left on during retrace, there will be two parallel lines visible on the CRT. Use the brighter line for the residual FM check (the dim line is the retrace indication).

i. Adjust the wavemeter slightly to move the sloping line to a convenient point on the graticule.

j. Observe the horizontal jitter in the line while the Δ F AMPLITUDE control remains fully CCW. The horizontal scale calibration made in Step h above will permit evaluating the frequency deviation of the jitter.

This deviation should be less than ± the Kc value indicated for "Maximum Residual FM" in Table 1-1. If excess residual FM is present, check the ripple voltage on the cathode supply [TP6 (-), TP3 (+ ; chassis ground)]. Use an oscilloscope with a 10:1 divider probe and operate the vertical channel with ac coupling. The ripple voltage should not exceed ± 0.01% of the cathode supply output voltage at any point. Refer to the trouble-shooting procedures for the cathode supply in the Model 650 Instruction Manual if excess ripple is present. If excess power supply ripple is not present, the excess residual FM may be due to arcing or other breakdown in the BWO tube, which requires replacement of the tube.

NOTE: If desired, the above residual FM checkout procedure may be repeated at other frequencies in the frequency range of the plug-in unit. Since arcing or other breakdown effects in a BWO tube often show up initially as excess residual FM, this procedure can be useful in evaluating performance of aging BWO tubes.

k. Make the following changes in control settings, in preparation for the residual AM test.

FREQUENCY Mode Selector to SINGLE
SINGLE Frequency Control to F_0
F_0 control set at high end of band
MODULATION to SQUARE WAVE

l. Adjust the wavemeter away from the frequency of interest, or remove it from the circuit completely, as desired. Make sure that sufficient attenuation is provided in the rf test loop to allow the crystal detector to operate in its square-law range.

m. Adjust the oscilloscope for a free-running horizontal sweep independent of the Model 650. Leave the oscilloscope vertical input ac-coupled. Adjust the oscilloscope vertical sensitivity to obtain a square-wave height of 5 scale divisions (5 cm) on the graticule.

n. Turn the MODULATION switch to AM OFF.

o. Without changing the vertical sensitivity vernier adjustment of the oscilloscope from the setting used to obtain a full-height display in Step m, set the oscilloscope vertical sensitivity switch to step-increase vertical amplification by a factor of 10 (so that the full-height square-wave presentation would now be 50 scale divisions). Adjust the zero position control as necessary to place the unmodulated power-on straight line trace at a convenient line on the graticule.

p. Observe the vertical ripple on the CRT trace. It must not exceed 1 scale division (i. e. less than 1/50 or 2% of the output amplitude). If excess residual AM is present, refer to the trouble-shooting procedures for the anode and -100 V supplies in the Model 650 Instruction Manual.

5.3.5 POWER CALIBRATION ADJUSTMENT. (See Figure 5-4.) The following adjustment procedure can be used to check and adjust the power output level of the plug-in unit.

a. For newly installed BWO tubes, check and adjust the anode voltage to the specified level using the ANODE ADJ control as directed in Paragraph 5.3.2. For adjustment of older tubes, proceed as follows:

b. Connect an rf test loop consisting of a suitable attenuator pad, a thermistor mount, and a power meter to the RF OUTPUT jack to measure absolute power. Be sure to use a large enough attenuator to avoid exceeding the thermistor power rating. Alternately, an ALFRED 8000/7051 Oscilloscope/Sweep Network Analyzer system can be used for making direct absolute power measurements with a crystal detector.

c. Make the following control settings:

RF OUTPUT to UNLEVELED
FREQUENCY Mode Selector to SWEEP $F_1 \rightarrow F_2$
MARKER AMPLITUDE to OFF
MODULATION to AM OFF
SWEEP TIME to 10
SWEEP TRIGGER to FREE RUN
F_1 to 0 on the logging scale
F_2 to 100 on the logging scale.

d. Observe the unleveled power output characteristic. If power at any point in the sweep is below the level specified in Table 1-1, increase the anode voltage slightly using the ANODE ADJ control.

NOTE: The ANODE ADJ. control permits an adjustment range of about ± 10 V. To provide a greater adjustment, particularly to restore the tube power output level after long service, it may be necessary to raise the anode voltage by more than the amount available from the ANODE ADJ. control. To do this, substitute a slightly higher resistance value for A12R14 (see Figure 5-8 in the Model 650 Instruction Manual), and then set the ANODE ADJ. control.

WARNING

Turn power off when changing A12R14.

CAUTION

Do not increase the anode supply voltage more than necessary to bring the minimum power point up to specifications. In addition, the anode supply voltage should never be adjusted so that the anode supply voltage, monitored as described in Paragraph 5.2 d, exceeds the maximum operating level shown in Addendum A or the tube data sheet. Anode current (monitored as described in Paragraph 5.2 h) must not be allowed to exceed the trip-out level specified in Addendum A (or the maximum current rating specified in Addendum A for instruments without the anode protection circuit). Also, helix current must not be allowed to exceed the specified maximum (trip out) level. Any increase in anode voltage over the factory setting shown in Addendum A will reduce the operating life of the BWO tube. Exceeding the voltage or current limits for the anode voids the warranty! If rated power output cannot be obtained with a reasonable anode voltage, and other tube operating voltages are correct, the BWO tube must be replaced.

e. For units with internal sampling, set the RF OUTPUT control to LEVELED and the RF SAMPLER switch to INT. Then check the leveled power characteristic across the band, and also check leveler response to the POWER LEVEL control. The maximum power output obtainable with full-band leveling should occur at a mid-range setting of the POWER LEVEL control, and should equal or exceed the level specified in Table 1-1. Also check the leveled power variation across the band. The variation across the entire band should not exceed the amount specified in Table 1-1. If the unit does not meet leveled output specifications, check the LEVELER BALANCE and INTERNAL SAMPLER SENS. adjustments as directed in Paragraph 5.3.2.

f. For units which require external sampling, set the RF OUTPUT control to LEVELED. Connect a suitable external rf sampler loop to drive the RF SAMPLER INPUT jack, as shown in Figure 5-3, by inserting a sampler or a coupler and detector between the RF OUTPUT jack and the attenuator pad. With a suitable sampler and a proper adjustment of the RF SAMPLER SENS. panel control, it should be possible to obtain full-band leveling with a mid-range setting of the POWER LEVEL control; and response to adjustment of the POWER LEVEL control above and below the full-band leveling point should be as described in the Model 650 Instruction Manual. The maximum power output obtainable with full-band leveling should approximately equal the level specified in Table 1-1. The leveled power variation across the band should not greatly exceed the amount specified in Table 1-1. (An optimum external sampler loop using flat components can achieve the minimum variation specifications given in Table 1-1.) If leveler performance is unsatisfactory and the external sampler loop is known to be adequate, check the LEVELER BALANCE adjustment as directed in Paragraph 5.3.2.

5.4 TROUBLE SHOOTING.

NOTE: Refer to Paragraph 5.4 of the Model 650 Instruction Manual. The following material is supplementary to that manual.

5.4.1 BWO TUBE AGING AND FAILURE. There are three general indications of BWO tube aging: (1) reduced rf output throughout the operating band; (2) complete loss of rf output at one or more frequencies in the operating band; (3) repeated tripout of the helix overcurrent protection relay when operating unleveled with full output power, particularly in the upper portion of the operating band. Indications (1) and (2) above are usually caused by reduced cathode emission, while gas ionization in the BWO tube causes indication (3). Indication (2) at either band limit can be caused by a defective cathode supply or a defective or mis-adjusted diode shaper board that produces cathode voltage outside the proper tuning range. Normal aging of the BWO tube does not produce frequency calibration error; but internal arcing or other breakdown can produce excess residual fm.

To localize trouble to the BWO tube when indications of the above type are present, check all tube voltages and currents in accordance with Paragraph 5.2 above, and make adjustments as necessary following the procedures of Paragraph 5.3. If proper operation is not restored with proper voltages applied, and the BWO tube is still in warranty, read the Tube Warranty and Replacement Procedure at the rear of this manual and follow the specified return procedure. If the tube warranty has expired, refer to the procedure of Paragraph 5.3.5 and try increasing the anode voltage above the normal level to restore power output, before discarding the tube.

NOTE: Where failure is due to gas ionization, no adjustment of voltages will restore normal, full-band operation. If desired, the tube can still be used within a restricted tuning range, at frequencies below the point where excessive helix current occurs.

5.4.2 LEVELER IMBALANCE OR FAILURE. When the LEVELER BALANCE adjustment is not set properly, the UNLEVELED light will not faithfully track the occurrence of fully leveled response over the band being swept. The light may stay on continually, or it may work OK with internal leveling but not on external leveling. An improper balance adjustment in the opposite direction can also produce excess overshoot on the rf trace turn-on at the end of the "retrace off" interval, and a lesser overshoot on individual cycles of square-wave modulation. When any of these indications occur, re-adjust the LEVELER BALANCE control as directed in Paragraph 5.3.2. If the LEVELER BALANCE adjustment cannot restore proper operation, make voltage measurements in the leveler-amplifier circuit under operating conditions, as indicated in Figure 4-4, to locate the defective component or to localize the trouble to the transfer oscillator or elevated supply.

5.4.3 LEVELER-AMPLIFIER COMPONENT SELECTION. After replacement of the BWO tube it may be necessary to change the values of starred components indicated on the schematic diagram and on Figure 4-4. If oscillatory amplitude variations occur in leveled operation, the capacitance value of A11C3 must be increased, and the value of A11R6 must be reduced so that the R-C product of A11R6 x A11C3 remains constant.

If the leveler response exhibits slow-rise characteristics, it may be necessary to reduce the capacitance value of A11C3. In that event, also increase A11R6 so that the product of A11C3 x A11R6 remains constant. The value of A11C3 must not be reduced enough to cause oscillatory leveler operation.

NOTE: The allowable adjustment range of A11C3 is 0.1 to 0.0005 µf (.022 µf nominal).

5.4.4 ELEVATED SUPPLY FAILURE. When failure is suspected in the Elevated Supply PC Board A12, all the passive components can be checked with power turned off. If the passive components are satisfactory, and the correct grid voltage is not produced with suitable drive from the modulator, check the performance of A12Q1 by substitution.

5.4.5 DIODE SHAPER BOARD FAILURE. If the proper voltages cannot be obtained when adjusting the START FREQ and END FREQ adjustment controls, and voltage measurements on the cathode supply feedback amplifier indicate that it is operating properly, check the performance of the diode shaper board. Typical operating voltages on the resistor biasing string are indicated in Figure 4-3. Performance of the diodes can be checked with power off by using an ohmmeter to measure forward and reverse resistance. To avoid overloads, do not use any range where open-circuit voltage exceeds 1.5 V, or short-circuit current exceeds 3 ma. In-circuit voltage checks may also be used to check A13Q1, A13Q2, A13CR13 and A13CR14.

5.4.6 INTERNAL SAMPLER FAILURE. If the instrument operates properly with an external sampler known to be in good condition, but performance with internal sampling is unsatisfactory, check the crystal detector on the internal sampler by substitution. If the internal sampler or its crystal detector are replaced, reset the Internal Sampler Sens. adjustment R13 following the procedure of Paragraph 5.3.2. If full-band leveling cannot be obtained at a suitable setting of the POWER LEVEL control with the Internal Sampler Sens. adjustment

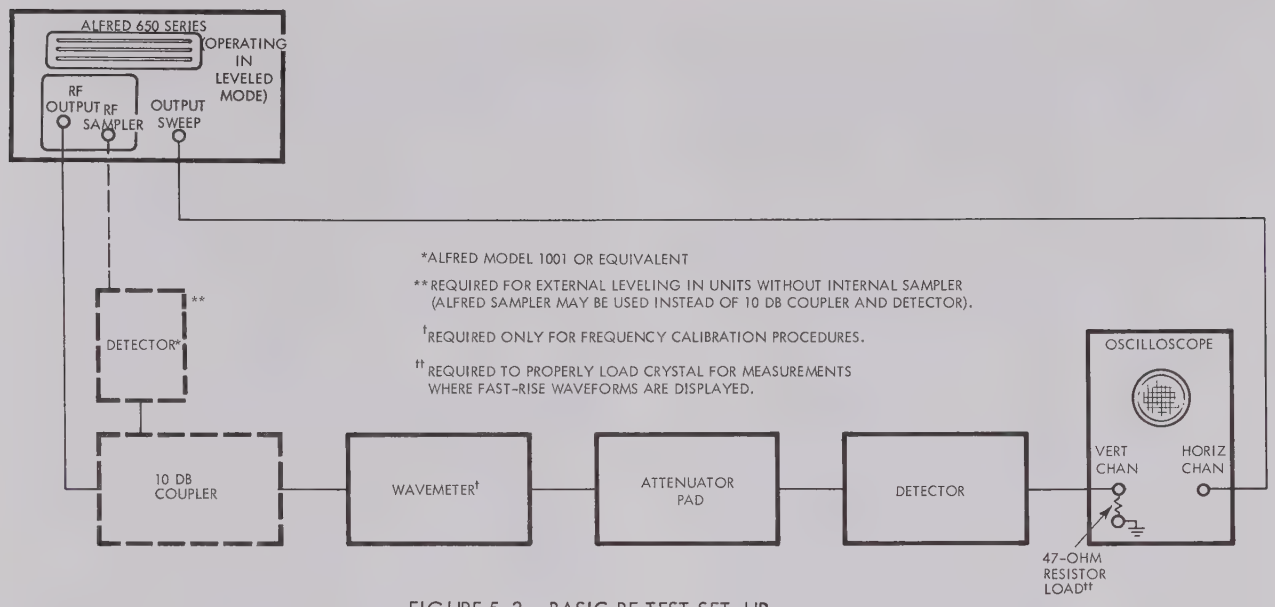

ALFRED 650 SERIES
(OPERATING IN LEVELED MODE)
RF OUTPUT
RF SAMPLER
OUTPUT SWEEP
*ALFRED MODEL 1001 OR EQUIVALENT
** REQUIRED FOR EXTERNAL LEVELING IN UNITS WITHOUT INTERNAL SAMPLER (ALFRED SAMPLER MAY BE USED INSTEAD OF 10 DB COUPLER AND DETECTOR).
† REQUIRED ONLY FOR FREQUENCY CALIBRATION PROCEDURES.
†† REQUIRED TO PROPERLY LOAD CRYSTAL FOR MEASUREMENTS WHERE FAST-RISE WAVEFORMS ARE DISPLAYED.
DETECTOR*
**
OSCILLOSCOPE
VERT CHAN
HORIZ CHAN
10 DB COUPLER
WAVEMETER†
ATTENUATOR PAD
DETECTOR
47-OHM RESISTOR LOAD††

FIGURE 5-3. BASIC RF TEST SET-UP

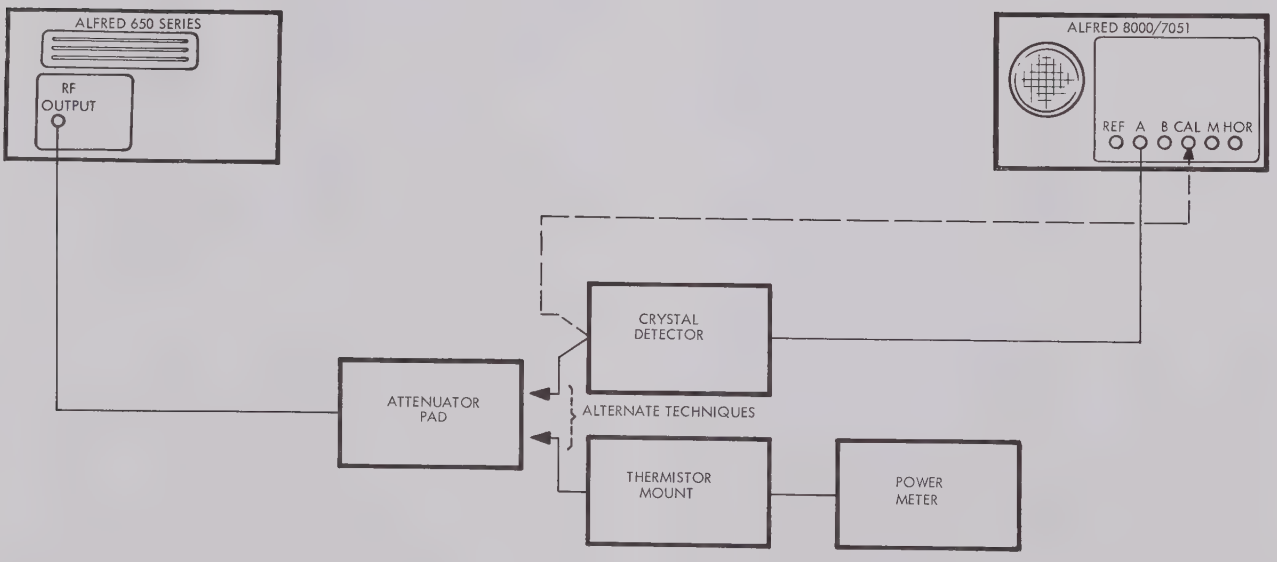


FIGURE 5-4. POWER CALIBRATION TEST SET-UP

properly set, try substituting a different resistance value for R14. A larger resistance value at R14 will tend to increase the sampler output level, thereby moving the full-band-leveling setting of the POWER LEVEL control in the CW direction.

5.4.7 FLAP ATTENUATOR FAILURE. Accidental entry of tools or foreign material into the waveguide RF OUTPUT connector may damage the flap of the attenuator. The condition of this flap can be determined by looking into the RF OUTPUT waveguide opening when the black POWER LEVEL control is turned CCW.

5.5 PARTS REPLACEMENT.

5.5.1 REPLACING THE BWO TUBE. Refer to Paragraphs 5.7.1 and 5.7.2 of the Model 650 Instruction Manual. After the tube is replaced, adjust operating voltages and reset the time meter as directed in Paragraph 5.7.5 and 5.7.6 of the Model 650 Instruction Manual. Then perform final frequency calibration in accordance with Paragraph 5.3.3 of this manual.

NOTE: Always retain the manufacturer's data sheet for the new tube for future reference, by placing it in the envelope at the rear of this manual. Since all tubes of the same model have the same maximum anode current rating (even though anode operating voltages vary), the factory-set anode protection circuit trip level should not need to be adjusted when a BWO tube is replaced.

5.5.2 REPLACING INDIVIDUAL CIRCUIT COMPONENTS. Refer to Figures 5-1 and 5-2 of this manual for the locations of circuit boards and major rf components. Parts on all PC boards are identified by silkscreened reference designators. These parts are also shown on the simplified schematics (Figures 4-3 and 4-4) and the overall schematics in Section 7. The proper soldering techniques for parts replacement are given in Paragraph 5.8 of the Model 650 Instruction Manual.

SECTION 6
PARTS LIST

PLUG-IN CHASSIS AND PC BOARD ASSEMBLIES

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION	SCHEMATIC
		Plug-in Chassis	C900774
A11	950621	Leveler Amplifier PC Board	C900730
A12		Elevated Supply PC Board	
	901488	(For instruments having Elevated Supply 901488)	C900869
	950620	(For instruments having Elevated Supply 950620)	C900729
A13		Diode Shaper PC Board	C900713
A19	951619	Anode Protection PC Board (Units with Varian tubes only)	B907307

A. HIGH VOLTAGE FEEDBACK BOARD †

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION
C1	12-30	Capacitor, fixed, ceramic, 1.5 pf, 6KV
R1 thru R6	52-464K	Resistor, fixed, MF, 464K, 1W, 1%

B. CHASSIS ASSEMBLY

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION
DS1	126-11	Lamp, clear, 110v
F1		Fuse, 2amp
R7	41-100K	Resistor fixed, comp., 100K, 1/2w, 10%
R8	39-69.8K	Resistor fixed, carbon, 69.8K, 1/2w, 1% (for use with M1 Time Meter)
R9	71-123	Resistor, variable, 2.5K
R10	(102-134)	Resistor, variable, 1K (part of S2)
R11	71-101	Resistor, variable, 250Ω
R12*		Resistor, Factory select
R13	71-122	Resistor, variable, 2.5K
R14*		Resistor, Factory select
R15	62-1	Resistor, fixed, comp., 10K, 10w, 10%
R16*		Resistor, factory select
R17*		Resistor, factory select

C. LEVELER AMPLIFIER PC BOARD A11
(Assembly 950636)

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION
A11C1 and A11C2	12-34	Capacitor, fixed, ceramic, .1 mf, 100 v
A11C3*	12-31	Capacitor, fixed, ceramic, .022 mf, 500v (alternate value, .01 mf, 500v)
A11CR1 and A11CR2	81-27	Diode, 1N625
A11Q1	81-113	Transistor, SP9965
A11Q2	81-114	Transistor, 2N3638A, alternate: 2N3250
A11Q3	81-73	Transistor, 2N706
A11Q4	81-72	Transistor, 2N699
A11R1	71-102	Resistor, variable, 100 Ω
A11R2	41-100 Ω	Resistor, fixed, comp., 100 Ω, 1/2 w, 10%
A11R3	41-6.8K	Resistor, fixed, comp., 6.8K, 1/2 w, 10%
A11R4	41-1.2K	Resistor, fixed, comp., 1.2K, 1/2 w, 10%
A11R5	41-560 Ω	Resistor, fixed, comp., 560 Ω, 1/2 w, 10%
A11R6		Same as A11R2
A11R7	41-1K	Resistor, fixed, comp., 1K, 1/2 w, 10%
A11R8	41-10K	Resistor, fixed, comp., 10K, 1/2 w, 10%
A11R9	41-470 Ω	Resistor, fixed, comp., 470 Ω, 1/2 w, 10%
A11R10	41-2.2K	Resistor, fixed, comp., 2.2K, 1/2 w, 10%
A11R11	41-3.3K	Resistor, fixed, comp., 3.3K, 1/2 w, 10%
A11R12		Same as A11R8
A11R13	41-56K	Resistor, fixed, comp., 56K, 1/2 w, 10%
A11R14 and A11R15	41-1M	Resistor, fixed, comp., 1M, 1/2 w, 10%

† On future production units, this assembly may be designated A25

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION
		D. ELEVATED SUPPLY PC BOARD (ASSEMBLY A12) PART NO. 950620 (Early Production) PART NO. 901488 (Later Production)
A12C1	12-28	Capacitor, fixed, ceramic, 0.001 mf, 6 kv
A12C2	12-1	Capacitor, fixed, ceramic, 15 pf, 600 v (in Assy. 950620)
	11-2	Capacitor, fixed, ceramic, 24 pf, 600 v (in Assy. 901488)
A12C3 and A12C4	12-3	Capacitor, fixed, ceramic, 0.01 µf., 500 v
A12CR1 and A12CR2	81-41	Diode, 1N459
A12CR3 and A12CR4	81-41	Diode, 1N459 (in Assy. 901488)
A12CR5 and A12CR6	81-156	Diode, Zener, 15 v, 1 w, MZ1000-17/1N4744 (in Assy. 901488)
A12Q1	81-72	Transistor, 2N699
A12R1	51-150K	Resistor, fixed, comp., 150 K, 1/2 w, ±5%
A12R2		Factory installed (see Addendum A)
A12R3	46-1 K	Resistor, fixed, MF, 1 K, 2 w, 5%
	46-820Ω	Alt. value 820 Ω (in Assy. 950620) Not used (in Assy. 901488)
A12R4	46-750 Ω	Resistor, fixed, MF, 750 Ω, 2 w, 5% Alt. value 820 Ω (in Assy. 950620)
	35-1.1K	Resistor, fixed, MF, 1.1 K, 2 w, 5% (in Assy. 901488)
A12R5	46-750 Ω	Resistor, fixed, MF, 750 Ω, 2 w, 5% (in Assy. 950620)
	50-820Ω	Resistor, fixed, MF, 820 Ω, 2 w, 5% (in Assy. 901488)
A12R6	41-1.8 K	Resistor, fixed, comp., 1.8 K, 1/2 w, 10% (in Assy. 950620)
	51-7.5 K	Resistor, fixed, comp., 7.5 K, 1/2 w, 5% (in Assy. 901488)
A12R7*	42-18 K	Resistor, fixed, comp., 18 K, 1w, 10% (in Assy. 950620)
	45-11K	Resistor, Factory Select, Nom. Value 11K, 1 w, 5% (in Assy. 901488)
A12R8	51-10Ω	Resistor, fixed, comp., 10 Ω, 1/2 w, ±5%
A12R9	71-103	Resistor, variable, 50 K, (cts type 201)
A12R10	56-237 K	Resistor, fixed, MF, 237 K, 1/2 w, 1%
A12R11	51-8.2K	Resistor, fixed, comp., 8.2 K, 1/2 w, ±5%
A12R12		Not used except as a substitute for A12R14 (see Addendum A)
A12R13	56-10 Ω	Resistor, fixed, MF, 10 Ω, 1/2 w, 1%
A12R14		Factory selected (see Addendum A)
A12R15		Factory-selected (see Addendum A) (in Assy. 901488)
A12R16		Not used
A12R17	51-180 K	Resistor, fixed, carbon film, 180 K, 1/2 w, 5%
A12R18	51-27 K	Resistor, fixed, carbon film, 27 K, 1/2 w, 5%
A12L1	92-22	Coil, RF, 33 µh
A12TP1 thru A12TP3	133-85	Jack, Test Point

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION
		E. DIODE SHAPER PC BOARD (ASSEMBLY A13; See Table 1-1 for Part No.'s)
A13C1 thru A13C3	12-34	Capacitor, fixed, ceramic, 0.1 µf, 100 v
A13C4	12-22	Capacitor, fixed, ceramic, 100 pf, 500 v
A13C5 and A13C6		Same as A13C1
A13CR1 thru A13CR14	81-41	Diode, 1N459
A13Q1 and A13Q2	81-115	Transistor, 2N3565
A13R1 thru A13R11		See Table 7-1 on schematic 900713C
A13R12 thru A13R14		Not used
A13R15	56-750Ω	Resistor, fixed, MF, 750Ω, 1/2 w, 1%
A13R16	56-121Ω	Resistor, fixed, MF, 121Ω, 1/2 w, 1%
A13R17 thru A13R23	56-100Ω	Resistor, fixed, MF, 100 Ω, 1/2 w, 1%
A13R24	56-80.6Ω	Resistor, fixed, MF, 80.6Ω, 1/2 w, 1%
A13R25	56-1K	Resistor, fixed, MF, 1K, 1/2 w,1%
A13R26	71-90	Resistor, variable, WW, 200 Ω, 20 turns
A13R27	41-1.8 K	Resistor, fixed, comp., 1.8 K, 1/8 w, 10%
A13R28	71-94	Resistor, variable, WW, 5K, 20 turns
A13R29	41-27K	Resistor, fixed, comp., 27K, 1/2 w, 10%
A13R30	41-10K	Resistor, fixed, comp., 10K, 1/2w, 10%
A13R31	41-150 K	Resistor, fixed, comp., 150 K, 1/ w, 10%
		F. BWO TUBE (See Table 1-1)
		G. OUTPUT LOW-PASS FILTER AND INTERNAL SAMPLER (As applicable; see Table 1-1)

H. A19 ANODE PROTECTION PC BOARD (Assy. 951619)[tt]

CIRCUIT REFERENCE	ALFRED PART NO.	DESCRIPTION
A19CR1	81-190	Diode, IN270
A19CR2 and A19CR3	81-20	Diode, IN4385
A19Q1	81-181	Transistor, 2N4889
A19Q2	81-114	Transistor, 2N3638A
A19Q3	81-182	Rectifier, Silicon controlled C106C1
A19Q4		Same as A19Q2
A19R1	51-10K	Resistor, fixed, comp., 10K, 1/2 w, ±5%
A19R2	71-99	Resistor, variable, comp., 100Ω, 2w
A19R3	51-22K	Resistor, fixed, comp., 22K, 1/2w, ±5%
A19R4 and A19R5	56-4.64K	Resistor, fixed, M.F., 4.64K, 1/2w, ±5%
A19R6	56-31.6K	Resistor, fixed, M.F., 31.6K, 1/2w, ±5%
A19R7	43-270Ω	Resistor, fixed, comp., 270Ω, 2w, ±10%
A19R8	41-4.7K	Resistor, fixed, comp., 4.7K, 1/2w, ±10%
A19R9	41-100Ω	Resistor, fixed, comp., 100Ω, 1/2w, ±10%

[tt] used only on units with Varian tubes

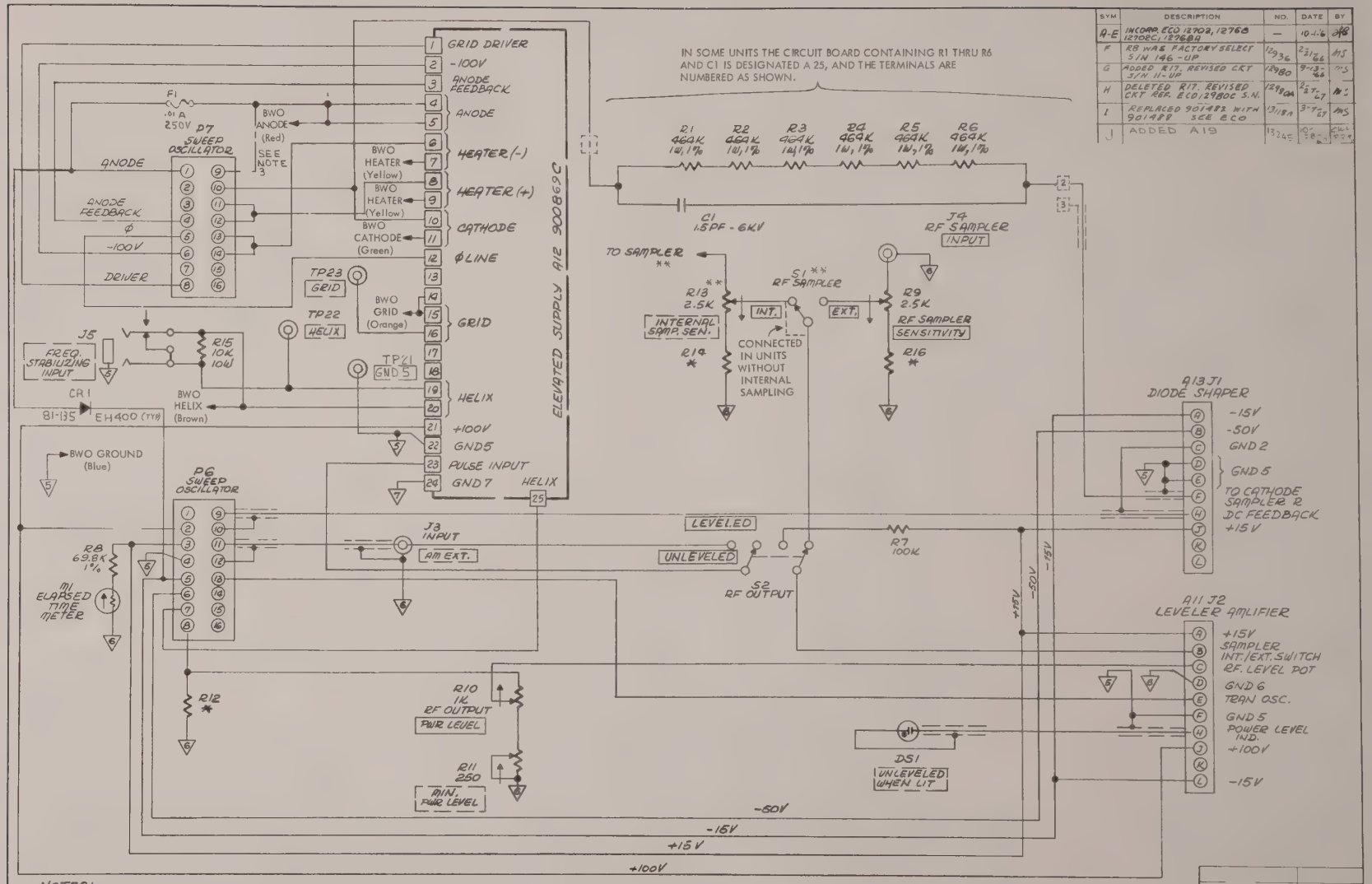
Factory-installed in later production units; field-installed in other units.

SECTION 7

SCHEMATIC DIAGRAMS

Schematics are included in the following order:

OVERALL CHASSIS SCHEMATIC	(900774C)	
ANODE PROTECTION PC BOARD A19	(907307B)	(On apron of 900774C)
LEVELER-AMPLIFIER PC BOARD A11	(900730C)	
ELEVATED SUPPLY PC BOARD A12	(900869C)	
DIODE SHAPER PC BOARD A13	(900713C)	



SYM	DESCRIPTION	NO.	DATE	BY
A-E	INCORP. ECO 12703, 12768, 12780, 12868, 12868	—	10-1-6	JHB
F	RB WAS FACTORY SELECT S/N 146 -UP	12936	2-21-66	MS
G	ADDED R17, REVISED CKT	12980	9-13-66	MS
H	DELETED R17, REVISED CKT PER ECO 12980C S.N.	12980A	2-27-67	MS
I	REPLACED 901482 WITH 901488 SEE ECO	13118A	3-7-67	MS
J	ADDED A19	13245	10-18-67	CW-1 10-24

NOTES:
1. UNLESS OTHERWISE SPECIFIED:
   1A. ALL RESISTOR IN OHMS, 1/2 W, 10%.
   1B. ALL CAPACITOR IN MICROFARADS, 500V.
   1C. ALL RESISTOR 1% ARE METAL FILM.
2. SQUARE (□) DESIGNATES TERMINAL CONNECTION ON ASSY "A12", 901488
3. JUMPER FOR ANODE VOLTAGE GREATER THAN 100 VOLTS.
4. * OPTIONAL, REFER TO ADDENDUM A OF INSTRUCTION MANUAL
5. ** INCLUDED ONLY ON UNITS WITH INTERNAL RF SAMPLER (K MODEL NO. SUFFIX)
6. TERMINALS 4 AND 5 OF A12 ARE INTERCONNECTED ON UNITS NOT HAVING ANODE PROTECTION CIRCUIT.

10/68

ITEM	REQD	PART NO.	DESCRIPTION

LIST OF MATERIAL

MATERIAL

MATERIAL STOCK NO

FINISH OR TREATMENT

DRAWN	Duane Y. Hess	DATE 10-16-65
ENG	G. Kahn	1-9-65
PROD	Alan D. Hudson	1-11-66

SCALE

SCHEMATIC PLUG-IN GRID LEVELING

DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005 ANGLE ± ½°
UNLESS INDICATED OTHERWISE

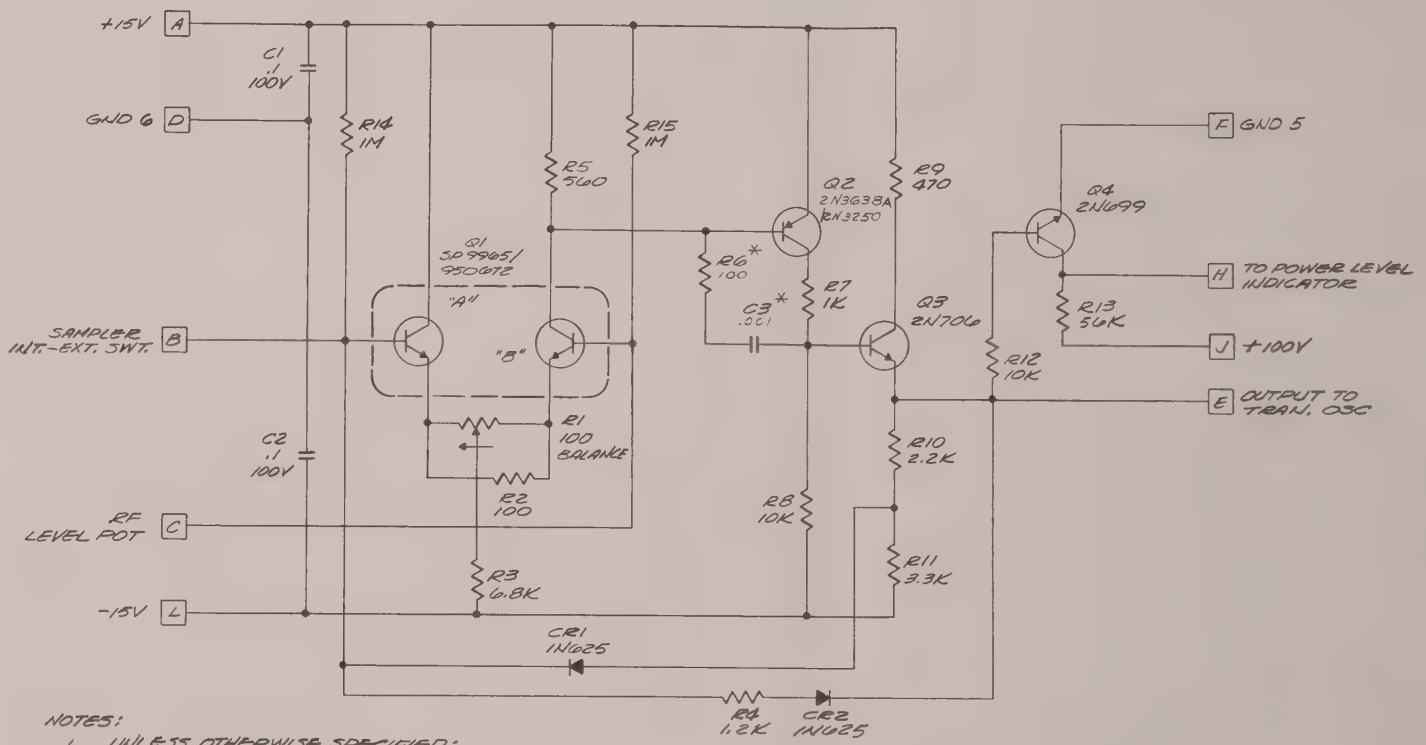
NEXT ASSY: 650 K.E.
USED ON

ALFRED ELECTRONICS
PALO ALTO CALIFORNIA

CAGE C | 900774-3 | REV J

SHEET 1 OF 1

SYM	DESCRIPTION	NO	DATE	BY
A	Q2 WAS 2N3250	12637	2-4-65	
B	REMOVED NOTE 4 R6 & C3 MADE FACTOR SEL.	12682	2-15-65	



NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   1A. ALL RESISTORS IN OHMS, 1/2W, 10%
   1B. ALL CAPACITORS IN MICROFARADS, 500V
2. SQUARES (□) DESIGNATES PRINTED CIRCUIT CONNECTION ON ASSY "A11", ASSY NO. 950621
3. PREFIX REFERENCE DESIGNATORS BY "A11" (I.E: A11R1, A11Q4)

* FACTORY SELECTED

ITEM	REQD	PART NO.	DESCRIPTION
			LIST OF MATERIAL

S/N 11	6521-34
SER NO. 11 & UP	650
NEXT ASSY	USED ON

MATERIAL —

MATERIAL STOCK NO —

FINISH OR TREATMENT —

DRAWN Vic Irow 9-13-64

END [signature] 1-4-65

PROD [signature] 1-11-65

SCALE —

SCHEMATIC LEVELER AMPLIFIER (GRID LEVEL)

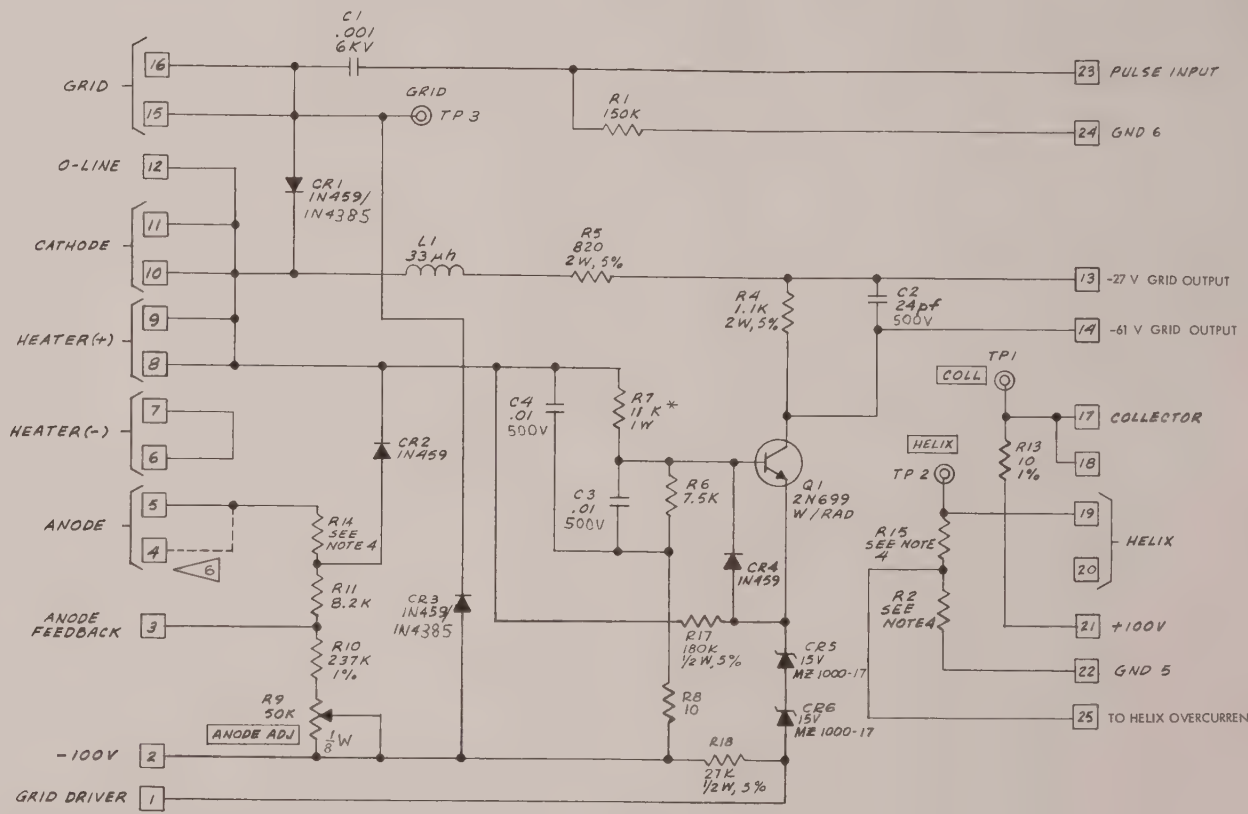
DIMENSIONS ARE IN INCHES
TOL: XX ± .015 XXX ± .005 ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

900730C

SHEET 1 OF 1

SYM	DESCRIPTION	NO	DATE	BY
A	CKT REVISED REFER TO ECO	13140	3-8-67	MS
B	CKT REVISED REFER TO ECO	13175	5/26/67	MS
C	ADDED NOTE 6	13245	10-18-67	C.W. [illegible]



REFERENCE DESIGNATIONS		
FIRST	LAST	NOT USED
C1	C4	
CR1	CR6	
L1	L1	
Q1	Q1	
R1	R18	R3,R12,R16

NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   - 1a. ALL RESISTORS IN OHMS, ½W, 10%
   - 1b. ALL RESISTORS VALUED 1% ARE METAL FILM.
   - 1c. ALL CAPACITORS IN MICROFARADS, 500V
2. SQUARES (□) DESIGNATE TERMINAL CONNECTIONS ON ASSY "A12" ASSEMBLY NO. 901488.
3. PREFIX REFERENCE DESIGNATORS BY "A12" (I.E.: A12R1, A12Q1)
4. REFER TO INSTRUCTION MANUAL.
5. ASSY P.C. BD. NUMBER IS 944126C

6 ON INSTRUMENTS USING THE ANODE PROTECTION CIRCUIT 951155, THE CONNECTION BETWEEN A12-4 & A12-5 IS BROKEN.

ITEM	REQD	PART NO.	DESCRIPTION
			LIST OF MATERIAL

901488	MS 19974-L1
901488	650 PLUG-IN
901488	6400
NEXT ASSY	USED ON

MATERIAL
MATERIAL STOCK NO.
FINISH OR TREATMENT

DRAWN M. SHEPPARD 11-27-66
ENG [signature] 5/4/67
PROD
SCALE

SCHEMATIC ELEVATED SUPPLY
650-3 -4 -5 6400

DIMENSIONS ARE IN INCHES
TOL: .XX ± .015, .XXX ± .005, ANGLE ± ½°
UNLESS INDICATED OTHERWISE

ALFRED ELECTRONICS
PALO ALTO, CALIFORNIA

SIZE C | 900869 | REV G

SHEET 1 OF 1

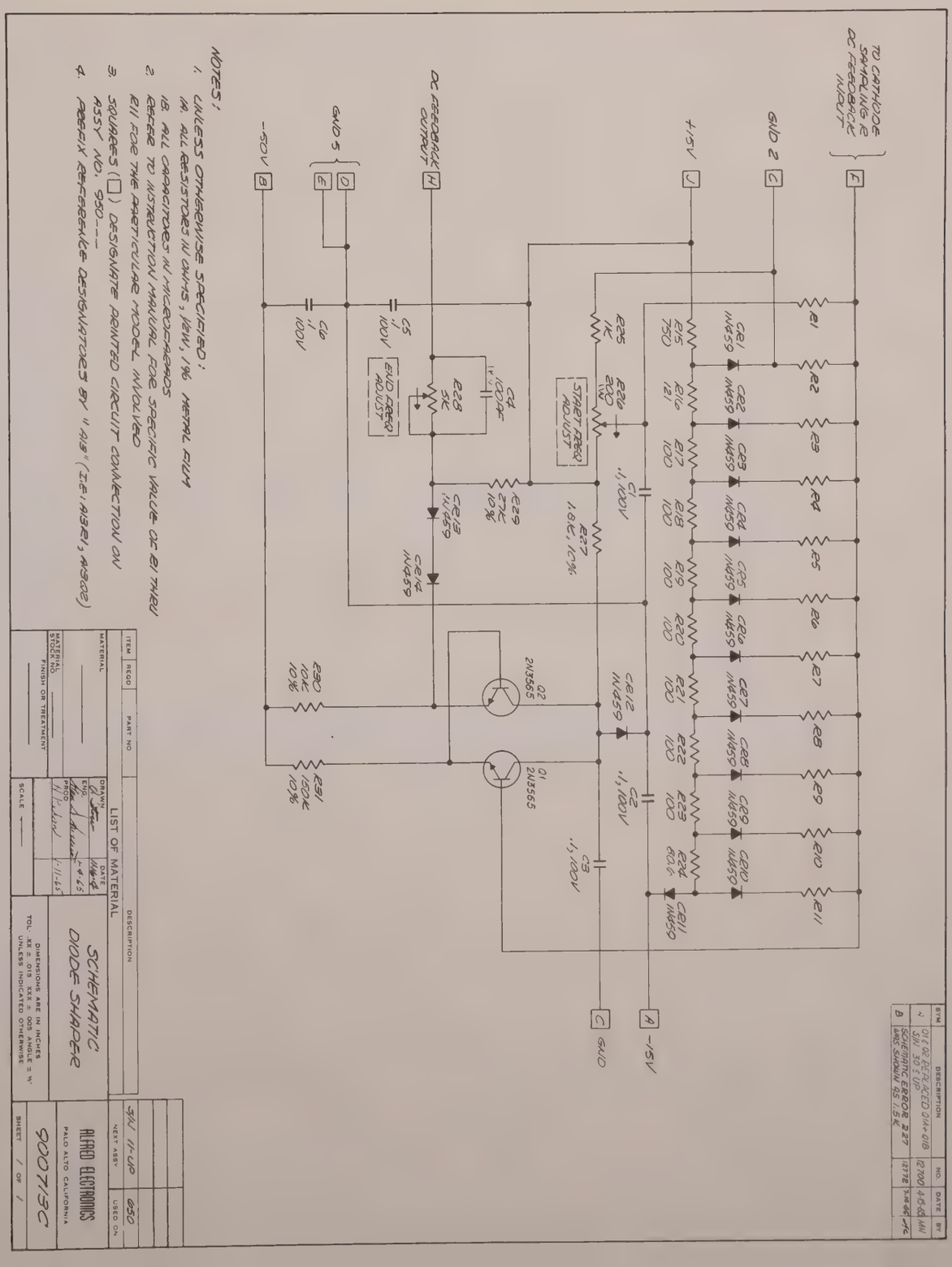
Table of Resistor Values for the Diode Shaper Assembly

Frequency GHz.	6400 Model No.	650 Model No.	Tube Manufacturer	Alfred Tube No.	Diode Shaper PC Board	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
1 to 2	6410 thru 6415	651 651C 651K 651CK	Stewart	112-029	950636	124K	165K	499K	475K	357K	562K	432K	422K	866K	261K	576K
1.4 to 2.5	6410-1 thru 6415-1	651-S1 651C-S1 651K-S1 651CK-S1	Stewart	112-034	950637	107K	340K	442K	576K	887K	412K	464K	1.15M	374K	412K	1.15M
1.7 to 4.2	6420-1 thru 6423-1	652-S5 652C-S5 652K-S5 652CK-S5	Stewart	112-033	950858	178K	102K	280K	261K	205K	187K	210K	154K	147K	137K	162K
2 to 4	* 6420 thru 6425	* 652 652C 652K 652CK	Watkins-Johnson	112-095	951877	107K	121K	750K	309K	422K	348K	287K	536K	267K	392K	383K
			Varian	112-015	951601	215K	274K	953K	887K	536K	604K	619K	634K	562K	487K	634K
3.5 to 6.75	6430-1 thru 6435-1	653-S1 653C-S1 653K-S1 653CK-S1	Stewart	112-035	950640	100K	121K	402K	383K	243K	301K	237K	374K	130K	340K	174K
			Varian	112-016	951602	226K	340K	768K	909K	866K	649K	576K	649K	562K	562K	453K
3.7 to 8.3	6430-2 thru 6433-2	653-S2 653C-S2 653K-S2 653CK-S2	Stewart	112-028	950965	158K	110K	316K	261K	226K	221K	178K	165K	154K	124K	110K
			Varian	112-017	951610	205K	147K	402K	374K	324K	294K	267K	237K	165K	412K	140K
4 to 8	6430 thru 6435	653 653C 653K 653CK	Stewart	112-027	950639	133K	133K	392K	340K	294K	274K	243K	215K	200K	187K	154K
			Varian	112-006	950932	215K	196K	499K	357K	324K	287K	261K	215K	178K	143K	143K
7 to 11	6440 thru 6443	654 654C 654K 654CK	Varian	112-012	950641	187K	866K	976K	1.15M	1.02M	953K	649K	698K	634K	576K	499K
			Watkins-Johnson	112-039	951699	86.6K	576K	806K	549K	866K	442K	665K	523K	324K	619K	422K
7 to 12.4	6440-1 thru 6443-1	654-S1 654C-S1 654K-S1 654CK-S1	Varian	112-012	950647	191K	274K	619K	536K	475K	402K	365K	316K	249K	249K	169K
			Watkins-Johnson	112-039	951603	82.5K	154K	357K	357K	301K	301K	255K	243K	215K	200K	182K
8 to 12.4	6450 thru 6453	655 655C 655K 655CK	Varian	112-013	950642	133K	465K	715K	649K	549K	536K	475K	392K	357K	294K	280K
			Watkins-Johnson	112-038	951604	634K	340K	453K	464K	442K	365K	324K	442K	267K	324K	243K
10 to 15.5	6460	656	Varian	112-014	950643	137K	549K	750K	715K	487K	536K	619K	453K	499K	549K	249K
12.4 to 18	6470 6471	657 657K	Varian	112-009	950644	133K	—	1.40M	768K	1.40M	604K	866K	536K	590K	715K	604K
18 to 26.5	6480	658	Varian	112-010	950645	150K	1.40M	1.24M	953K	909K	750K	825K	634K	649K	442K	324K
26.5 to 40	6490	659	Varian	112-011	950646	110K	464K	634K	619K	549K	475K	442K	392K	294K	357K	243K

* ALT. SHAPER 950638

Frequency GHz.	6400 Model No.	650 Model No.	Tube Manufacturer	Tube No.	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
2 to 4	6420 thru 6425	652 652C 652K 652CK	ALT. TUBE Stewart	SE 215A-2	124K	133K	383K	332K	340K	280K	301K	267K	232K	221K	232K

† 650



NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   1A. ALL RESISTORS IN OHMS; 1/2W, 1% METAL FILM
   1B. ALL CAPACITORS IN MICROFARADS
2. REFER TO INSTRUCTION MANUAL FOR SPECIFIC VALUE OF R1 THRU R11 FOR THE PARTICULAR MODEL INVOLVED
3. SQUARES (□) DESIGNATE PRINTED CIRCUIT CONNECTION ON ASSY NO. 950---
4. PREFIX REFERENCE DESIGNATORS BY "A9" (I.E., A9R1, A9C2)

ITEM	REQD	PART NO	DESCRIPTION	MATERIAL
			LIST OF MATERIAL	

MATERIAL SPEC NO. ——— FINISH OR TREATMENT ———

DRAWN [signature] DATE 1-9-65
ENG [signature] DATE 1-9-65
PROD [signature] DATE 1-11-65
SCALE ———

SCHEMATIC DIODE SHAPER

DIMENSIONS ARE IN INCHES
XX ± .015 XXX ± .005 ANGLE ± ½°
UNLESS INDICATED OTHERWISE
TOL:

ALFRED ELECTRONICS
PALO ALTO CALIFORNIA

900736

NEXT ASSY 5PU UP
USED ON 650

SHEET 1 OF 1

SYM	DESCRIPTION	NO.	DATE	BY
A	ONE 02 DELETED ADD 4 OHM SHU 30 S UP	12700	4-5-65	JAN
B	SCHEMATIC ERROR 2.27 MISS SHOWN AS 1.5K	13772	7-14-65	PC

ALFRED

TUBE REPLACEMENT

All TWT and BWO tubes furnished in ALFRED instruments are available from ALFRED ELECTRONICS for either warranty or out-of-warranty replacements. Current prices are given on the Replacement Tube Price List.

TUBE WARRANTY

The following warranties are applicable to tubes used in catalog instruments only. For the warranty applicable to tubes used or for use in special or modified instruments, please check with the factory. All tube warranties are from date of shipment by ALFRED.

WARRANTY FOR TWT AND VTM

Tubes are warranted unconditionally against defects in workmanship, materials, and construction within the period shown in Column A and the number of heater hours shown in Column B. To supplement the unconditional warranty, the tubes are warranted on a pro-rata basis for the rated number of heater hours shown in Column C or for one year, both computed from the date of original shipment by ALFRED, whichever expires first. The pro-rated adjustment will be based on the current list price of the tube and the unused percentage of heater hours (Column C) or one-year time period, whichever results in lesser credit.

Warranty Condition*	Tube Type	Applicable Tube Group or Alfred Tube Part No. Series	A Mo.	B Hours	C Hours
WC2	VTM	112-001 and 112-003	2	100	1000
WC3	TWT	10 and 20 mw output except WC4 tubes	12	500	2000
WC4	TWT	112-040 and 112-047	12	2000	-
WC5	TWT	1 watt output except WC6 and WC7 tubes	12	1500	-
WC6	TWT	112-046, 112-065, & 112-072	12	1000	-
WC7	TWT	112-057, 112-080, & 112-081	12	250	1000
WC8	TWT	2 to 10 watt output except WC9 tubes	12	75	500
WC9	TWT	112-055	2	50	500

* WC# denotes the corresponding warranty period(s) shown in the right-hand column(s) and is used for cross-reference to this warranty statement from other documents.

WARRANTY FOR ALL BWO TUBES

Tubes are warranted unconditionally against defects in workmanship, materials, and construction within the period shown below, without regard to the number of heater hours used.

Warranty Condition*	Tube Type	Warranty
WC10	BWO	Warranted unconditionally for one (1) year.

WARRANTY CONDITIONS APPLY ONLY TO TUBES LISTED ABOVE WHICH ARE USED IN ALFRED CATALOG INSTRUMENTS.

This warranty applies only to tubes sold after July 1, 1969.

TUBE SERVICE REPORT

TO OBTAIN WARRANTY CREDIT THE TUBE SERVICE REPORT MUST BE COMPLETED AND RETURNED WITH THE TUBE.

RETURN PROCEDURE

In case a tube or instrument fails, please contact the factory or your local sales representative for advice or authorization to return either the tube or the instrument to the factory. NO TUBE OR INSTRUMENT WILL BE ACCEPTED FOR REPAIR OR CREDIT ADJUSTMENT WITHOUT WRITTEN AUTHORIZATION AND ACCOMPANYING SERVICE REPORT.

When the authorization is received, pack the tube in a rigid container (use original carton if available) at least 4" larger than the tube in each dimension. Wrap the tube with 1/4" of soft padding material and heavy kraft paper before placing in container. Pack at least 2" of resilient dunnage such as rubberized hair, foam, or similar shock absorbing material completely around the tube. Mark the container "FRAGILE" and ship PREPAID via air freight, air express or rail express. Do not ship via parcel post or air parcel post since experience has shown that fragile items are more apt to be damaged when shipped via these methods.

Use similar wrapping, packing and shipping provisions for an instrument. At least 6" of rubberized hair (or equivalent shock absorbing material) is required for an instrument.

IN-WARRANTY FAILURE - BWO AND VTM TUBES

BWO and VTM tubes which fail in warranty will be replaced with a new tube. In case a tube fails, please issue a purchase order for a new tube at the tube list price and return the defective tube. Warranty credit will be issued and deducted from the price, subject to tube manufacturer's verification that failure was caused by tube malfunction. To qualify for maximum credit, it is essential that the defective tube be properly packed and returned within 30 days after failure.

REPAIRABLE OR IN-WARRANTY FAILURE - TW TUBES

If the returned tube is found to be repairable, the user will be asked to issue a purchase order for repair charges determined by the original tube manufacturer. In general, the repair will be at no cost if the tube is in warranty and there is no evidence of misuse or abnormal conditions of operation.

WARRANTY CREDIT

Any applicable credit allowed under the terms of this warranty applies only toward the purchase of a replacement tube from ALFRED ELECTRONICS. Cash settlements will not be made. In terms of this warranty, a replacement tube must be the same type as that on which credit is allowed. Credit for one tube only may be applied toward the purchase of a single replacement tube. Warranty credit remains in effect for a maximum of six (6) months from date ALFRED ELECTRONICS notifies the customer. All credits will be based on the purchase price of the tube which prevails at the time the order for a replacement tube is received by ALFRED ELECTRONICS.

BWO RF CABLES

RF OUTPUT CABLE MUST ACCOMPANY BWO TUBES returned for warranty credit, repair or replacement. If rf output cable is NOT returned, the cable price is added to the normal BWO repair or replacement charge. For prices see Replacement Tube Price List.

SPECIAL CONDITIONS

If a returned tube or instrument proves not to be defective after test and evaluation at ALFRED ELECTRONICS, the tube or instrument will be returned at the customer's expense.

The final determination as to whether the tube failed in normal operation thereby bringing it under the applicable warranty or whether the tube was misused thereby excluding it from application of the warranty provisions, lies solely with the tube manufacturer.

Data, warranty credit, and prices subject to change without notice.

8/1/69

ALFRED ELECTRONICS

Service Report

Instrument Model _____ Serial No. _____ Date Received _____

TW/BWO Tube Type _____ Serial No. _____ Date Received _____

Date First Tested _____ Date Placed in Service _____ Date of Failure _____

Total Number of Hours of TWT/BWO Heater Operation _____

_____

1. Was operation normal just prior to failure? Yes _____ No _____
2. If not, what was done to adjust it? _____

_____

_____

3. Has proper cooling been maintained during tube operation? _____

_____

4. Did helix overcurrent tripout occur? _____

_____

5. Was environment normal? (specify) _____

_____

6. Symptoms - (describe failure) _____

_____

_____

7. Operating conditions at time of failure (indicate any unusual conditions) _____

_____

_____

8. Name of person to contact regarding evaluation of failure _____

Telephone No. _____ Signature _____

Title _____

Date _____

ALFRED

TUBE REPLACEMENT

All TWT and BWO tubes furnished in ALFRED instruments are available from ALFRED ELECTRONICS for either warranty or out-of-warranty replacements. Current prices are given on the Replacement Tube Price List.

TUBE WARRANTY

The following warranties are applicable to tubes used in catalog instruments only. For the warranty applicable to tubes used or for use in special or modified instruments, please check with the factory. All tube warranties are from date of shipment by ALFRED.

WARRANTY FOR TWT AND VTM

Tubes are warranted unconditionally against defects in workmanship, materials, and construction within the period shown in Column A and the number of heater hours shown in Column B. To supplement the unconditional warranty, the tubes are warranted on a pro-rata basis for the rated number of heater hours shown in Column C or for one year, both computed from the date of original shipment by ALFRED, whichever expires first. The pro-rated adjustment will be based on the current list price of the tube and the unused percentage of heater hours (Column C) or one-year time period, whichever results in lesser credit.

Warranty Condition*	Tube Type	Applicable Tube Group or Alfred Tube Part No. Series	A Mo.	B Hours	C Hours
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WC8	TWT	2 to 10 watt output except WC9 tubes	12	75	500
WC9	TWT	112-055	2	50	500

* WC# denotes the corresponding warranty period(s) shown in the right-hand column(s) and is used for cross-reference to this warranty statement from other documents.

WARRANTY FOR ALL BWO TUBES

Tubes are warranted unconditionally against defects in workmanship, materials, and construction within the period shown below, without regard to the number of heater hours used.

Warranty Condition*	Tube Type	Warranty
WC10	BWO	Warranted unconditionally for one (1) year.

WARRANTY CONDITIONS APPLY ONLY TO TUBES LISTED ABOVE WHICH ARE USED IN ALFRED CATALOG INSTRUMENTS.

This warranty applies only to tubes sold after July 1, 1969.

TUBE SERVICE REPORT

TO OBTAIN WARRANTY CREDIT THE TUBE SERVICE REPORT MUST BE COMPLETED AND RETURNED WITH THE TUBE.

RETURN PROCEDURE

In case a tube or instrument fails, please contact the factory or your local sales representative for advice or authorization to return either the tube or the instrument to the factory. NO TUBE OR INSTRUMENT WILL BE ACCEPTED FOR REPAIR OR CREDIT ADJUSTMENT WITHOUT WRITTEN AUTHORIZATION AND ACCOMPANYING SERVICE REPORT.

When the authorization is received, pack the tube in a rigid container (use original carton if available) at least 4" larger than the tube in each dimension. Wrap the tube with 1/4" of soft padding material and heavy kraft paper before placing in container. Pack at least 2" of resilient dunnage such as rubberized hair, foam, or similar shock absorbing material completely around the tube. Mark the container "FRAGILE" and ship PREPAID via air freight, air express or rail express. Do not ship via parcel post or air parcel post since experience has shown that fragile items are more apt to be damaged when shipped via these methods.

Use similar wrapping, packing and shipping provisions for an instrument. At least 6" of rubberized hair (or equivalent shock absorbing material) is required for an instrument.

IN-WARRANTY FAILURE - BWO AND VTM TUBES

BWO and VTM tubes which fail in warranty will be replaced with a new tube. In case a tube fails, please issue a purchase order for a new tube at the tube list price and return the defective tube. Warranty credit will be issued and deducted from the price, subject to tube manufacturer's verification that failure was caused by tube malfunction. To qualify for maximum credit, it is essential that the defective tube be properly packed and returned within 30 days after failure.

REPAIRABLE OR IN-WARRANTY FAILURE - TW TUBES

If the returned tube is found to be repairable, the user will be asked to issue a purchase order for repair charges determined by the original tube manufacturer. In general, the repair will be at no cost if the tube is in warranty and there is no evidence of misuse or abnormal conditions of operation.

WARRANTY CREDIT

Any applicable credit allowed under the terms of this warranty applies only toward the purchase of a replacement tube from ALFRED ELECTRONICS. Cash settlements will not be made. In terms of this warranty, a replacement tube must be the same type as that on which credit is allowed. Credit for one tube only may be applied toward the purchase of a single replacement tube. Warranty credit remains in effect for a maximum of six (6) months from date ALFRED ELECTRONICS notifies the customer. All credits will be based on the purchase price of the tube which prevails at the time the order for a replacement tube is received by ALFRED ELECTRONICS.

BWO RF CABLES

RF OUTPUT CABLE MUST ACCOMPANY BWO TUBES returned for warranty credit, repair or replacement. If rf output cable is NOT returned, the cable price is added to the normal BWO repair or replacement charge. For prices see Replacement Tube Price List.

SPECIAL CONDITIONS

If a returned tube or instrument proves not to be defective after test and evaluation at ALFRED ELECTRONICS, the tube or instrument will be returned at the customer's expense.

The final determination as to whether the tube failed in normal operation thereby bringing it under the applicable warranty or whether the tube was misused thereby excluding it from application of the warranty provisions, lies solely with the tube manufacturer.

Data, warranty credit, and prices subject to change without notice.

8/1/69

ALFRED ELECTRONICS

Service Report

Instrument Model _____ Serial No. _____ Date Received _____

TW/BWO Tube Type _____ Serial No. _____ Date Received _____

Date First Tested _____ Date Placed in Service _____ Date of Failure _____

Total Number of Hours of TWT/BWO Heater Operation _____

_____

1. Was operation normal just prior to failure? Yes _____ No _____
2. If not, what was done to adjust it? _____

_____

_____

3. Has proper cooling been maintained during tube operation? _____

_____

4. Did helix overcurrent tripout occur? _____

_____

5. Was environment normal? (specify) _____

_____

6. Symptoms - (describe failure) _____

_____

_____

7. Operating conditions at time of failure (indicate any unusual conditions) _____

_____

_____

8. Name of person to contact regarding evaluation of failure _____

Telephone No. _____ Signature _____

Title _____

Date _____

SHIPMENT DAMAGE CLAIM

The instrument should be tested as soon as it is received. If it fails to operate properly or is damaged in any way, a claim must be filed with the carrier. Have carrier agent inspect damage to instrument and packing crate and forward us a copy of his written report. You will then be advised of replacement or repair arrangements and disposition of the equipment. Please include model number, type number and serial number when referring to this instrument for any reason.

WARRANTY

ALFRED products are warranted against defects in workmanship and materials. This warranty is limited to repair or replacement of products or parts (except tubes, transistors, and batteries) which prove defective within one year after delivery to original purchaser. ALFRED ELECTRONICS is not liable for consequential damage.

If any fault develops:

1. Notify us, giving full details of the difficulty, including the model number, type number and serial number. Upon receipt of this information, you will be sent service instructions or shipping data.

2. Upon receipt of shipping instructions, forward the instrument prepaid and repairs will be made at the factory. If requested, an estimate of the charges will be made before the work begins when instrument is not covered by this warranty.

PACKING

The instrument should be packed in the original carton. If unusable or not available, use a wooden box with approximately three inches of excelsior or other shock-absorbing material surrounding the instrument. If desired, packing services of a local transfer and storage company may be employed.